FINAL DESIGN ANALYSIS

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ORIGINAL

N.W. BOUNDARY CONTAINMENT / TREATMENT SYSTEM

PN 36.2

MCA-FY81

ROCKY MOUNTAIN ARSENAL

Commerce City, Colorado

MARCH 1983

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THIS DOCUMENT PROVIDES GEOLOGICAL AND TECHNICAL INFORMATION NEEDED TO DESIGN THE NORTHWEST BOUNDARY SYSTEM. PART I DEFINES THE SCOPE OF THE PROJECT. PART II DISCUSSES GEOTECHNICAL ELEMENTS TO BE CONSIDERED, SUCH AS HYDROLOGY OF THE AREA, SITE GEOLOGY, AQUIFER CHARACTERISTICS, AND PUMP TEST RESULTS.
DESIGN CONCEPTS OF THE BARRIER AND WELLS ARE PRESENTED. PART III PROVIDES PUMP TEST DATA, SOIL CLASSIFICATION SHEETS, GRADATION CURVES, CUTOFF WALL HYDRAULIC ANALYSIS, AND MODELING RESULTS.

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CONCEPT DESIGN ANALYSIS FOR NW BOUNDARY CONTAINMENT PN 37 ROCKY MOUNTAIN ARSENAL

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PART I - GENERAL DESCRIPTION

PART I - GENERAL DESCRIPTION

1. **PROJECT SYNOPSIS.**

1.1 **PURPOSE.** This project provided structures and equipment to intercept a contaminated plume of ground water upgradient of the Rocky Mountain Arsenal boundary; to convey the water to and from a treatment plant; and to redistribute the treated water to the natural flow pattern. The treatment plant was a separate design.

1.2 **AUTHORIZATION.**

1.2.1 **Directives**, Directive No. 2, 8 January 1982, Design FY 82 MCA - Rocky Mountain Arsenal. Directive No. 1, 14 January 1983, FY 81, PN 36.2 Liquid Waste Disposal, Phase II - WPC.

1.2.2 **Scope.** The project included discharge wells with pumping equipment, piping to a central treatment plant influent sump, the central treatment plant influent and effluent sumps, effluent pumps, distribution piping and recharge wells. Support for the wells included well access roads, power, controls, potable water and sewage disposal for the treatment plant, and site preparation for the treatment building. The hydraulic capacity requirement for the system was estimated to be 1500 gallons per minute.

1.2.2.1 **Authorized Scope/Cost Limitation.** The Project Development Brochure Rev. No. 2, dated 31 March 1982 requested $4.8 million. The PDB was based on providing 52 discharge wells, 26 recharge wells, 45 monitoring wells, 22,500 L.F. of electrical distribution, 6,000 L.F. of collection and redistribution piping, and a 3,800 S.F. treatment building with carbon absorption equipment. The dewatering system proposed would have consisted of two rows of 26 discharge wells apart parallel to the Arsenal boundary 2,000 feet and 2,500 feet inside the boundary.

1.2.2.2 **The Project Designation** was changed to FY 81 PN 36.2 Liquid Waste Disposal - Phrase II - WPC with an estimated cost of 5.8 million.

1.2.2.3 **Design Scope/Cost Estimate.** The Cost Estimate for this design is furnished with these documents. The scope on which the estimate is based is shown on the final drawings and described in this Design Analysis under the Design Requirements and Provisions. Reduction of the dewatering system to a single row of 15 discharge wells is the most significant deviation from the PDB. The utility runs and support facilities have been reduced correspondingly. The number of wells and spacing were revised to adapt to the hydrologic conditions encountered in the hydrogeologic investigations.

1.3 **CRITERIA.**

1.3.1 Directive No. 2, 8 January 1982, Design FY 82 MCA - Rocky Mountain Arsenal.

1.3.2 Rev No. 2, 31 March 1982, Project Development Brochure Liquid Waste Disposal Facility - Northwest Boundary Containment and Treatment Facility.

1.4 PROJECT DESCRIPTION.

1.4.1 Construction Site. The project is located along the Northwest Boundary Rocky Mountain Arsenal, Colorado, parallel to Colorado Highway 2. The area is located in open, undeveloped grassland in Section 22, Township 2 South, Range 67 West, 6th Principal Meridian.

1.4.2 Function. The facilities constructed remove Nemagon (DBCP) contamination from the groundwater crossing the Arsenal boundary without reduction or change in pattern of the natural flow. Groundwater is pumped from a row of discharge wells, treated by carbon absorption and returned through recharge wells to the aquifer. This design did not include the treatment building and equipment, the design of discharge and recharge wells isolate the contaminated plume for treatment and reinjection compatible with the existing conditions.

1.4.3 Personnel and Equipment. Normal operation requires one part-time operator. The system requires daily observation on a year round basis. The semiautomatic control system contains malfunction alarms which require operator response. Well service equipment is required on an occasional basis.

1.4.4 Constructibility. The system was designed for a one-time operation of approximately 10 years, the anticipated duration of the plume of contamination. Most of the equipment has a normal service life of 20 to 30 years. The wells and piping system could be used for much longer, if they were to be needed. Materials normally used in well and water service are generally compatible with the ground water. Some special materials were used due to the organic nature of the contaminants. Plastic pipe was used in buried piping to avoid corrosion and scaling problems.

1.5 ECONOMIC SUMMARY. The hydraulic barrier required to intercept the contaminated plume fixes both construction, operation, and maintenance costs. In order to optimize the length, depth, and location of the barrier the test holes and hydraulic models discussed in Part 2 of this design analysis were required.

PART II

DESIGN REQUIREMENTS AND PROVISIONS

RMA
N.W. BOUNDARY
CHAPTER I - HYDROGEOLOGY

1. GENERAL GEOLOGY.

1.1 **PHYSIOGRAPHY.** Rocky Mountain Arsenal (RMA) is located within the Colorado Piedmont Section of the Great Plains physiographic province. This section consists of a late mature to old elevated plain with the low rolling topography. The site itself is located on the eastern edge of the broad valley of the South Platte River, east of the foothills of the Front Range of the Rocky Mountains. Topographic relief across the entire Arsenal is approximately 200 feet, with the land surface generally sloping northwest toward the South Platte River.

1.2 **DESCRIPTION OF OVERBURDEN.** The overburden consists primarily of alluvial clays, sands, silts, gravels, and some cobbles in various combinations. Above the bedrock, the soils are quaternary alluvial deposits ranging from 0 to 70 feet in thickness, with irregular, braided channel deposits and lenses characteristic of alluvium. Occasional calcareous cemented zones occur in the alluvium and may vary from several inches to several feet in thickness. The alluvium is overlain in places by more recent deposits of windblown silts and sands.

1.3 **BEDROCK STRATIGRAPHY.** The Denver and Arapahoe Formations are the bedrock units immediately underlying the Rocky Mountain Arsenal. They consist of deltaic shales, claystones, sandstones, and conglomerates. The Denver Formation is younger and overlie the Arapahoe Formation. The thickness of the Denver Formation at the Arsenal is approximately 250 + 0400 feet. Occasional lignite beds are known to occur locally in the Denver Formation. In the N.W. Boundary area, the Denver Formation consists predominantly of shale or claystone, with irregular, discontinuous sandstone lenses. The sandstone lenses are thought to be deltaic channel deposits that grade laterally and vertically into fine-grained shales and claystones.

1.4 **BEDROCK STRUCTURE.** RMA is situated in the northwestern portion of the Denver Basin. The basin is an oval shaped structural depression measuring approximately 120 by 70 miles. The basin is filled with approximately 15,000 feet of sedimentary rocks, composed mostly of shales, sandstones, and conglomerates, with lesser amounts of limestone. The bedrock immediately underlying RMA has a gentle regional dip to the southeast.

2. **FIELD EXPLORATION SUMMARY.** Field work for the project began on March 18, 1982 and was completed in January, 1983. A total of 89 holes were drilled. Refer to sheet C-5 for boring locations. Depths varied from 31.6 feet to 77.3 feet. Sixty-seven (67) of the borings are located in five lines parallel to the northwest boundary. The remaining 22 holes include 5 wells and 17 observation wells (piezometers) which were installed to perform and monitor aquifer pump tests. Pump test data was used to determine aquifer characteristics and well efficiency. Aquifer pump tests were conducted in the vicinity of DH82-13 and DH82-6A.

2.1 EQUIPMENT AND PERSONNEL. Except for wells W-1, W-2, and W-3, all drilling was performed by COE drill crews and drill rigs. A CME-75 equipped with a hollow stem auger, a Bucyrus-Erie churn, and a Failing 1500 were the three drill rigs used for this project. The majority of the holes were drilled with the CME. In augered holes 3-inch or 2-inch split spoon samples were taken every 2-1/2 or 5 feet. Churn-drilled holes were sampled continuously. Wells W-1, W-2, and W-3 were drilled under contract by Caissons, Inc. The 36-inch diameter wells were drilled using a rotary rig with a flight auger. Well W-4 was drilled with the Failing 1500 and W-5 was drilled with the churn drill.

2.2 BORING LOCATIONS AND PURPOSE. Five lines of borings were drilled parallel to the northwest boundary in sections 22 and 27. The lines are located approximately 200, 800, 1,600, 2,400, and 3,400 feet southeast of the boundary (see sheet C-5). Potential boring locations were staked every 200 feet, but all locations were not drilled. As a result, spacing between drilled holes was either 200 or 400 feet. Only the holes drilled are shown on the boring location plan, which explains the gaps in the boring numbering system. The holes were drilled through the overburden and about 5 feet into bedrock to determine the following: the elevation of top of bedrock; the composition of bedrock; the stratigraphy and composition of the alluvium; and the elevation of the groundwater surface, if present. If groundwater was encountered in the holes, 2-inch diameter piezometers were installed for water level measurements and water sampling for water quality determination. The first four lines inside the boundary were situated along three potential locations for the containment system. The fifth line, located 3,400 feet southeast of the boundary in section 22, was drilled to clarify complex hydrology and to determine contaminant flow paths. Borings W-5A and W-5B were drilled to investigate the sandstone lense located in the vicinity of well W-5.

2.3 PUMP TEST WELLS AND PIEZOMETERS. Five wells (numbered W-1 through W-5) and 17 piezometers were installed to perform and monitor aquifer pump tests. See Figures 1 and 2 for well and piezometer locations and layouts. W-1 and W-3 were tested for well efficiency (see paragraph 1.4.3.4.4) and used as observation wells (piezometers) for the main pump test which was run in W-4. W-2 was originally going to be the main pump test well, but was not used due to lack of capacity. It is believed that the drilling and development methods used resulted in a very inefficient well, thereby not producing sufficient discharge to adequately stress the aquifer during the pump test. W-4 was constructed to replace W-2, and was the well used for the main pump test. A 12-inch diameter boring was drilled using rotary drilling methods, with Revert as the drilling fluid additive. It was constructed with steel casing and an 8-inch diameter, stainless steel, 60 slot, continuous wire wound screen. Twelve piezometers were installed in four directions from W-4 to monitor water levels during the pump test. Well W-5 was installed to perform an aquifer pump test in thin portions of the aquifer. An 8-inch diameter boring was drilled utilizing the churn drill.

The well was constructed with steel casing and a 6-inch diameter, 90-slot, stainless steel wire wound screen. This well was drilled with a churn drill so no drilling fluid would be required. While drilling well W-4, significant quantities of drilling fluid were lost into the aquifer. Drilling continued, at times, without any fluid return at all. This would tend to move fines into the aquifer. As a result, the permeability around the well and the efficiency of the well can be reduced. Because W-5 was situated in a thinly saturated area, it was essential that the well be constructed as efficiently as possible with minimal damage to the aquifer. Churn drilling offers these advantages because no drilling fluid is necessary. Five piezometers were installed in two directions from W-5 to monitor water levels during the pump test. The borings for the piezometers were drilled with the hollow stem auger.

2.4 PIEZOMETER CONSTRUCTION. Most of the piezometers were 2-inch diameter schedule 80 PVC pipe with threaded couplings installed in 7 7/8-inch diameter borings. Screens were slotted, Schedule 80, PVC pipe with .020-inch (20 slot) size. Towards the end of the exploration program, Schedule 40 PVC pipe with glued couplings was used in lieu of Schedule 80. Piezometers with glued couplings were installed strictly for water level information and are not intended for water quality sampling. The piezometers were gravel packed with pea gravel to the top of the aquifer and sealed above the gravel pack with a bentonite plug or impervious drill cuttings. The remainder of the annular space around the riser pipe was backfilled with drill cuttings and sealed near the ground surface with another bentonite plug.

2.5 BACKFILLING HOLES. Borings that did not have piezometers installed in them were backfilled with drill cuttings.

3. SITE GEOLOGY.

3.1 BEDROCK.

3.1.1 Lithology.

The drilling revealed that the bedrock in the Northwest Boundary Study area is comprised of the Denver Formation. The Denver Formation was found to consist of clay shale or silty clay shale, grading in character from highly weathered to unweathered. The uppermost shales are usually found to be highly fractured and weathered. Sandstone lenses were encountered in several holes. The sandstone units vary from soft to hard, depending on the amount of weathering and degree of cementation. They are relatively impervious due to a large fraction of fines. The sandstones encountered were occasionally saturated. Although several sandstone lenses were encountered during the subsurface investigations, the sandstone encountered while drilling well W-5 will have the most impact on the containment system, because it lies under the proposed slurry cutoff wall. Rock cores of this material were obtained and are stored at RMA for display. The sandstone at this location is a moderately hard, argillaceous

sandstone. The color varies from bluish-gray (unweathered) to yellowish-brown (weathered). The lower 5 feet is essentially unweathered, while the upper 5 feet varies from moderately to highly weathered. Undisturbed samples were obtained and a slug test was performed to determine the permeability of this sandstone lense. The undisturbed samples were sent to the MRD lab for permeability tests. The lab testing has not been completed as of this writing. The slug test is discussed later in the report.

3.1.2 Bedrock Topography and Structure. Depths to the top of the Denver Formation range from 20 to 70 feet, and the bedrock displays several channel-like valleys and benches (see sheet C-4). The regional dip of the bedrock strata is very gentle. The bedrock surface topography is the result of stream scour. There is a good discussion on the bedrock erosional surface presented in the 1961 report "Program for Reclamation of Surface Aquifer," prepared by the Corps of Engineers, Omaha District. A 1,000-foot-wide paleochannel in bedrock extends northward from below the northwestern quarter of Section 27 to below the southwestern quarter of Section 22. There, the paleochannel turns northwestward and crosses beneath the Northwest Boundary 800 feet north of 9th Avenue. This paleochannel has an average bedrock elevation of 5070 m.s.l. A fairly level bedrock surface extends south of this paleochannel and averages 5085 feet in elevation. A 1,000-foot-wide bedrock bench borders the northeast side of the paleochannel north of 9th Avenue and lies at an average elevation of 5085 feet. This will be referred to as Bench I. A still higher bedrock bench, Bench II, lies at an elevation of 5110 to 5125 feet and parallels the paleochannel beneath the eastern halves of Sections 22 and 27. This bench is approximately 1,000 feet wide and is somewhat dissected by small filled "gullies." The largest of these extends northward then westward on Bench II beneath the southeastern quarter of Section 22. It then cuts down slightly into Bench I and intersects the largest paleochannel near the Northwest Boundary. The section of Bench II beneath Section 27 has an uneven surface due the small buried gullies, but has topographic relief of 10 feet or less. Slumping may have been an important process in the development of the bedrock topography. A possible buried slump block lies on Bench II beneath the southeastern corner of Section 27. It probably detached from the steep bedrock slope that bounds Bench II to the east. The slope rises to bedrock highs that generally lie at elevations of 5145 feet. These highs may be the dissected remains of a still older Bench III. A large bedrock knob beneath the western part of Section 23 reaches an elevation of 5160 feet as does bedrock beneath the southern edge of Section 27. These are probably erosional remnants. One deep buried "gully" dissects this bedrock highland and extends northwestward from below the southwest corner of Section 26. This "gully" loses definition when it intersects Bench II. Bedrock does not crop out at the surface in the study area.

3.2 ALLUVIUM. The alluvium was deposited during the Quaternary Period. It was deposited primarily by tributaries of the ancient Platte River drainage system.

3.2.1 Alluvial Aquifer Material.

3.2.1.1 Lithology. In most places, the bedrock is directly overlain by unconsolidated coarse alluvium. This is the alluvial aquifer material and consists of highly permeable sands and some gravels with varying amounts of silt. The majority of lab-classified samples of the material were determined to be silty gravelly sands, with the percent of fines ranging from 6 to 20 percent. In an isolated case silt content in a silty gravelly sand reached 32 percent. Clean sands (-5% fines) and clean sand/gravel mixes are intermixed (at random) throughout the aquifer. Some lenses of less permeable clayey sand, sandy clay, and clay are interbedded with the sands and gravels. These usually comprise less than 20 percent of the total thickness of the aquifer material.

3.2.1.2 Thickness and Distribution. The thickness of the alluvial aquifer material ranges from over 25 feet to less than 5 feet. Thicknesses exceed 20 feet in the large paleochannel, and exceed 25 feet over the dissected bedrock highs of Bench III beneath the northwest quarter of Section 26. Over the steep bedrock slopes that bound the benches, the thicknesses usually decrease to 5 feet or less. Over the remnant bedrock knobs, aquifer material is commonly absent. Groundwater elevations rarely equal the elevations of the top of the aquifer material, though confined conditions are found near the Northwest Boundary in the south part of Section 22 and the north part of Section 27.

3.2.2 Confining Layer. The alluvial aquifer material is overlain by fine-grained overbank alluvial sediments. This material can act as a confining layer to groundwater. The fine-grained sediments are usually sandy or silty clays, lean clays, or less commonly, highly plastic clays. Some zones of clayey sands are occasionally encountered. The thickness of these fine-grained sediments generally average 25 feet.

3.2.3 Cemented Zones.. Cemented zones are known to occur at random in the alluvium at RMA. A cemented sand and gravel was encountered in boring DH82-45A at a depth of 20.8 to 23 feet. Although this was the only cemented zone reported during the exploratory program, it is possible that more exist and were not detected. It is not uncommon to drill through these cemented zones without detecting them because the drilling action breaks down the cementing agent, resulting in cuttings that have the appearance of uncemented alluvium. Cemented zones, if encountered, will have minimal impact on well drilling operations, but can have considerable impact on the slurry trench excavation. Therefore, the possibility of encountering cemented zones will have to be addressed in the contract documents.

3.3 EOLIAN DEPOSITS. In many areas of the arsenal, a thin mantle of eolian soils overlie the alluvial deposits. These Wisconsin Age deposits were derived from glacial outwash material. They are generally a fine grained, fairly uniform silty sand.

4. HYDROLOGY.

4.1 **REGIONAL HYDROLOGY.** Regional and arsenal wide studies were conducted by Geraghty and Miller, Inc., and is presented in their January 1981 report "Evaluation of the Hydrogeologic System and Contamination Migration Patterns, Rocky Mountain Arsenal, Denver, Colorado." Some of their conclusions are presented below. Refer to Geraghty and Miller's report for more detailed information.

CONCLUSIONS:

a. Groundwater is obtained from alluvial deposits and bedrock aquifers. Principal bedrock aquifers, from land surface down, are the Denver, Arapahoe, Laramie, Fox Hills, Dakota, and Fountain-Lyons Formations.

b. The alluvial deposits laid down in ancient erosional valleys have a maximum thickness of about 140 feet on the Arsenal and extend into the South Platte River Valley. Where sufficiently thick and saturated, this aquifer is capable of yielding large supplies of water.

c. The Denver Formation crops out at the land surface. It consists of carbonaceous shales and claystones with occasional sandstone and siltstone lenses. These lenses range in thickness from a few feet to 20 feet and occupy sinuous channels that are difficult to trace but in some areas extend for at least 3,000 feet.

d. The Denver Formation is separated from the underlying Arapahoe Formation by a clay/shale buffer zone, 75 to 200 feet thick.

e. The Arapahoe Formation is the most important aquifer in the Denver area. It yields good quality water and is tapped by some 6,000 stock, domestic, and municipal wells.

f. Depth to the Arapahoe aquifer below the RMA land surface varies from 700 feet along the south boundary to 300 feet along the north boundary.

g. Recharge to the groundwater system is from precipitation on the outcrop area, infiltration of surface water, and vertical leakage from confining beds. Total recharge to the Arapahoe-Denver sequence in the Denver Basin is estimated at 100 mgd.

h. Pumpage from the Arapahoe-Denver aquifers approaches 150 mgd and is in excess of recharge. Groundwater is being taken from storage within the aquifers and this withdrawal has resulted in a 100 to 200 foot waterlevel decline in the Denver area.

i. Regional groundwater flow is from south to north in the deep artesian aquifers. This flow pattern has been modified by pumpage in the Denver region. The potentiometric surface of the Arapahoe aquifer below the RMA in 1978 was at an elevation of 5,000 to 5,100 feet above msl.

j. Water-table elevations range from 5,300 feet in the southeast corner of the RMA to 5,100 feet along the northern boundary. Regional flow is northward toward the South Platte River Valley. Excluding local anomalies, the regional water-table flow pattern found during this 1980 study is identical to that of 1956.

k. The quality of groundwater in the vicinity of the Arsenal varies considerably. Water in the alluvial aquifer along the South Platte River is mineralized and unsuitable for domestic and municipal supplies. As irrigation water it is of salinity-hazard classification. Water in the bedrock aquifers is less mineralized and of fair to good quality.

l. Groundwater flow occurs in both alluvium and bedrock aquifers and is part of one continuous hydrologic system as indicated by mapping of equipotential lines. Generally speaking, the amount of groundwater flow in the bedrock aquifer is small compared to that in the alluvium.

m. Contours on the water table show the existence of a 30-foot high mound below the South Plants. This mound is due to leakage of water from pipes into low-permeability material.

n. This man-made anomaly of the water table presently is a major driving force of the groundwater flow system on the Arsenal. Flow lines from the mound radiate in all directons and the head differential between the mound and the northwest boundary is 145 feet, equivalent to a high gradient of about 0.01 ft/ft.

o. Equipotential lines indicate a vertical component of groundwater throughout the Arsenal and water from the alluvium can migrate to deeper formations. Vertical flow has been identified in the South Plants and Basin A "Neck" areas.

4.2 <u>BEDROCK (DENVER FORMATION)</u>. Except for the investigations (slugtest) conducted in the sandstone lense located in the vicinity of W-5, no specific hydrologic investigations were conducted in the bedrock for this project because information provided by RMA states that no contaminants in excess of state water standards have ever been detected in the bedrock along the northwest boundary.

4.2.1 The hydrology of the Denver Formation has previously been studied and tested by WES and is presented in detail in their 1980 report "Hydrologic Assessment of Denver Sands Along the North Boundary of RMA," and in their 1982 (draft) report "Hydrogeology of Rocky Mountain Arsenal, Colorado." These reports provided the following major conclusions:

(a) The Denver Formation, in conjunction with the near-surface alluvial aquifers, comprises the local groundwater regime at RMA. The Denver-Alluvial contact roughly parallels the ground surface in most areas.

(b) The Denver Formation underlies the entire Arsenal and reaches a maximum thickness of approximately 400 ft.

(c) The Denver Formation is truncated by the alluvium-covered land surface. The base of the Denver is dipping to the southeast.

(d) The Arsenal is divided into two distinct regions based on variations in lithologies within the Denver Formation. From C Street to the west, the near-surface Denver Formation is predominantly clay shale with thin lenticular layers of silty sand (SM). From C Street east, the Denver Formation is much more variable and contains beds of coal, lignite, mappable volcaniclastic zones, and thick (up to 50 ft.) permeable sand (SM, SP).

(e) Hydrologic conditions in the groundwater regime at RMA are controlled by variables in both the Alluvium and the Denver Formation. The complex interaction of these variables determines the hydrologic characteristics for a specific part of the Arsenal within a certain time frame.

(f) Many local areas of the Arsenal have extreme water table fluctuations due to boundary conditions such as pumping wells, lakes and impoundments. The Arsenal-wide flow patterns, excluding local anomalies, have remained relatively constant since 1956 (i.e., to the northwest).

(g) The "mound" of groundwater under the Shell Plant area and the "ridge" of groundwater extending across Section 36 are man-made anomalies produced by impounded surface water and things like leaking water pipes.

(h) Much of the recharge to the local groundwater regime at RMA is from the alluvial aquifer inflow from the southeast (i.e., the very large buried channel) and from artesian inflow from the Denver Formation.

(i) Piezometric heads in many of the Denver wells indicate water is flowing laterally (up-dip) through the Denver sediments and entering the alluvium. The large head drops in the Denver aquifer reported by Robson and Romers (1982) for some areas in the Denver Basin do not show up in the Regional Denver wells.

(j) The "mounding" of groundwater in the Shell Plant, Basin A and Basin A "Neck" areas provide the head needed to drive contaminated groundwater vertically into the Denver locally, but the piezometric heads show that this water should then flow laterally back into the alluvium at a lower elevation.

(k) The piezometric levels for many Denver wells in areas away from the anomalous "mounds" are often higher than water levels in the alluvium at the same site (indicating slight artesian conditions).

(l) The hydraulic conductivity in the more permeable Denver sands (SM-SP) is approximately 10^{-3} to 10^{-4} cm/sec.

(m) The permeability of jointed clay-shale was 0.19×10^{-4} cm/sec. Permeability of unfractured/unweathered clay-shale is approximately 10^{-7} cm/sec.

4.2.2 <u>Slug Test in W-5A.</u>

4.2.2.1 <u>Installation.</u> The hole was drilled by first churning through the overburden and installing 6-inch diameter steel casing to top of bedrock. The sandstone was then cored using a rotary rig with PQ coring equipment. Clean water was used as the drilling fluid while coring. No additives were added. The bedrock portion of the hole was later reamed to 5-7/8-inch diameter. A 2-inch diameter, schedule 40 PVC, piezometer was installed for the slug test. A 5-foot long slotted PVC screen was placed in the lower 5 feet of sandstone. A 5-foot long bentonite seal was placed in the annular space above the screen to prevent upward seepage during the test and ensure injected water is flowing into the sandstone and not back up the hole. A gravel pack (pea gravel) was installed around the screen. A detailed installation diagram along with the slug test calculations are presented in Appendix __.

4.2.2.2 <u>Slug Test.</u> The test was conducted on 25 January 1983. Exactly 1.5 gallons of water were added to the piezometer. The water level drop was then monitored for 2 hours. After 2 hours, the water level dropped to within about 0.3 foot of the original water level.

4.2.2.3 <u>Water Level Data Aquisition.</u> Changes in water level were measured using a battery-operated downhole head measuring device. The device consists of a pressure transducer, a digital voltmeter, and a strip chart recorder. The amplified transducer output was monitored with the voltmeter and recorded on the strip chart. The digital voltmeter output was converted to depth of water above the transducer by a predetermined calibration factor of 0.075 volts per foot of depth. The voltage was read and recorded at 15 second intervals throughout the test. The voltage was later converted to water levels.

4.2.2.4 <u>Data Analyses.</u> The data was analyzed in the same manner as presented in the USGS Professional Paper 708 "Ground-Water Hydraulics" 1972. Based on this slug test, the permeability of the sandstone at this location is approximately 4 to 5×10^{-5} cm/sec. Considering this is two orders of magnitude more permeable than the slurry wall, it will have to be removed for the full width of the trench.

4.3 ALLUVIUM.

4.3.1 Water Table and Unsaturated Areas. The water table in the Northwest Boundary study area lies at elevations ranging from less than 5090 to more than 5150 feet m.s.l. (see sheet C-14). The water table over the large paleochannel and the level bedrock surface beneath the western part of the study area has a relatively gentle gradient ranging from .0023 to .005 foot/foot sloping to the north-northeast. The water table elevations in this area range from 5105 to 5090 feet. The bedrock high to the north and east causes the direction of flow to change abruptly to the northwest over Bench I. Numerous unsaturated areas, roughly coincident with Bench II and higher bedrock elevations extend west of the paleochannel. These unsaturated areas are separated by narrow "bands" of flowing groundwater roughly coincident with the small buried "gullies" incised in the bedrock. Water table elevations in these areas range up to 5150 feet. Gradients are relatively steep and range as high as .05 foot/foot directed to the west-northwest. This groundwater enters the study area from the east-southeast. However, the source of the water moving through material in the deep buried "gully" beneath the southeast corner of Section 27 is probably separated from the source of the water flowing over Bench III as evidenced by different levels of contaminants. The alluvium beneath the northeastern part of Section 22 and the western part of Section 23 is largely unsaturated. Some water will flow in the alluvium in this area due to infiltrated precipitation. This causes the water table surface to slope directly away from the unsaturated area. Some groundwater was encountered in the alluvium above the bedrock high to the north of the proposed containment system. Any connection between this groundwater (elevation ± 5110) and the groundwater along the containment system (elevation ± 5090) is unclear at this time. However, it is highly possible that the groundwater above the bedrock high will flow down the bedrock slope and mix with the lower groundwater on both sides of the cutoff wall. There is no containment presently proposed for this groundwater, because information provided by RMA states that the water above this bedrock high has never had contaminant levels in excess of the state water standards. It should be pointed out, however, that if this water ever becomes contaminated and mixes with the groundwater down-gradient of the cutoff wall it may be mistaken as failure of the wall. For this reason, a minimum of two monitor wells are proposed to monitor the alluvial groundwater above the bedrock high to the north of the cutoff wall. Should these wells ever indicate the ground water is contaminated, it should be contained with an extension to the northwest boundary cutoff wall.

4.3.2 Saturated Thicknesses. Saturated thicknesses in the alluvial aquifer range from 0 to over 25 feet (see sheet C-15). The largest saturated thicknesses (25 feet and more) are in the material in the paleochannel beneath the western part of the study area. The aquifer is occasionally confined in this area. The saturated thickness generally decreases as the bedrock elevation rises. Saturated thicknesses decrease to less than 10 feet over Bench I. Saturated thicknesses over Benches II and III are generally less than 5 feet and often less than 2 feet. Groundwater in this area flows as small "rivulets" in the small buried "gullies." The

width of these rivulets is generally small and this made pinpointing exact flow paths difficult. Along the proposed containment system the saturated thickness decreases from over 20 feet at the southwest end to as little as 5 feet at the northeast end (see sheet C-12). In general, the southwest half of the system has a saturated thickness of approximately 20 feet and the saturated thickness of the northeast half is less than 10 feet. As a result, the aquifer and containment system for each half was analyzed individually.

4.3.3 <u>Fine-Grained Confining Layer</u>. The hydrology of the confining layer was not studied in detail since this layer seldom interacts with groundwater in the study area other than to confine the water table in areas, and to transmit natural recharge. The hydraulic conductivity of this fine-grained alluvium is negligible compared to the underlying sands.

4.3.4 <u>Hydraulic Analysis - Alluvial Aquifer</u>. Two alluvial aquifer pump tests were run to determine the hydraulic characteristics of the aquifer in the vicinity of the proposed containment system. One (W-4) was conducted near DH 82-13 in the northwest quarter of Section 27, by Woodward-Clyde Consultants and Omaha District personnel with some technical assistance from the US Geological Survey, Denver. The other (W-5) was performed near existing monitor well 22-13 in Section 22, by Omaha District personnel only. Pump test locations are shown on sheet C-5. Each of the pump tests are discussed separately.

4.3.4.1 <u>Pump Test in Well W-4</u>.

4.3.4.1.1 Sixteen 2-inch diameter PVC monitoring wells and three 12-inch diameter PVC observation wells were installed in the vicinity of Well No. W-4 for the purpose of measuring groundwater drawdown and recovery during the pump test. Existing monitor well 27-045 was also monitored during the test. The layout of the wells used during the test is shown in Figure 1. In addition, four 3/4-inch diameter PVC piezometers were installed in the gravel packs around each of the wells W-1, W-2, and W-3. These piezometers extended to various depths and were located at various distances from the well within the gravel pack.

The pumped well, W-4, was an 8-inch diameter steel-cased well with 20 feet of 8-inch diameter .060-inch slot wire-wound stainless steel well screen. Approximately 5 feet of 8-inch diameter pipe extends below the bottom of the screen into weathered shale bedrock functioning as a sediment trap. The pumping well was installed in a 12-inch diameter boring drilled with a Failing 1500 truck-mounted drill rig using conventional rotary drilling techniques and bio-degradable organic drilling fluid (Johnson's Revert). A 3/4-inch diameter PVC piezometer was attached to the outside of the well casing. The piezometer extends to the bottom of the well screen and the lower 5 feet of the piezometer was slotted.

The well does not have an artificial gravel pack and was naturally developed with a surge block. Sediments were removed from the well with a sand bailer. After surging and bailing, the well was pumped at approximately 395 gallons per minute for 40 minutes. Drawdown and recovery of the ground-water was monitored in the pumped well and the adjacent wells during this mini-pump test which was performed in the afternoon on May 24.

4.3.4.1.2 <u>Drawdown Test</u>. During the 48-hour test, a 6-inch diameter 22.5 horsepower Franklin submersible pump was positioned within the lower one-third of the well screen. A 3/4-inch diameter PVC pipe was installed in the well to facilitate water level measurements in the well during pumping. The drawdown test began in well W-4 at 08:35:43 a.m. on 26 May 1982. The well was pumped continuously at a rate of about 400 gallons per minute (gpm) ±5 percent for 48 hours. The pumping rate was monitored in the dishcarge line at the well using a Rockwell totalizer flowmeter. The total flow indicated in gallons on the meter was recorded at approximately the same time intervals used to monitor the drawdown in the observation wells. The average flow rate during each time interval was determined as the difference in the flowmeter reading divided by the elapsed time between the current and previous reading.

The ground water was pumped through a 4-inch diameter irrigation pipe across a small topographic divide and discharged through a 6-inch diameter circular orifice weir approximately 700 to 800 feet southeast of the pumping well. Flow through the orifice was monitored on an occasional basis as a check on the flow meter.

The pumping rate was controlled by a gate valve located in the discharge line near the pumping well. The pump was powered by a U.S. Army Corps of Engineers truck-mounted diesel generator capable of supplying 230 volts.

4.3.4.1.3 <u>Water Level Data Acquisition</u>. Water level measurements were initially taken at intervals of 30 seconds or less and gradually increased to about 90 minutes at 3 hours and remained at 90-minute intervals to the end of the test. With the exceptions of observation wells 12D, SE4, W-1, and W-3, water level measurements were obtained using electric water level indicators (sounders) and steel tapes (wetted tape method). Electric sounders were used in many of the wells during the early portions of the drawdown and recovery tests when the most rapid response of the aquifer was anticipated. After about 3 hours, the wetted tape method was used exclusively with the exception of the 3/4-inch diameter piezometers (near W-1, W-2, W-3, and W-4) where, because of the small diameters, the ability to obtain water levels was limited to the electric sounders.

Water levels in wells W-1 and W-3 were monitored with float type water level recorders which were installed by the U. S. Geological Survey, Denver.

Changes in water level in wells 12D and SE4 were measured using two battery-operated downhole head measurement devices. Each device consists of a pressure transducer. The amplified transducer output was monitored using a digital voltmeter and strip chart recorder. The digital voltmeter output was converted to a depth of water above the transducer by a predetermined calibration factor (0.075 volts per 1 foot of depth). The strip chart recorders were used to automatically record the change in voltage and, therefore, the change in head during the first hour of the drawdown test and about the first half hour of the recovery test. However, because of internal noise in the recorders, the digital voltmeter readings were recorded manually at the specified observation time intervals. The transducers are sensitive to changes in water depth of .01 feet. Manual measurements using the wetted tape method were used at some of the longer time intervals to complement and check the downhole head measuring devices.

4.3.4.1.4 Recovery Test. The recovery test began at 8:40 a.m., 28 May 1982, and concluded 24 hours later. Some additional measurements were made during the following 48-hour period. Water levels during recovery were measured as described in the drawdown test.

4.3.4.1.5 Aquifer Description. Boring logs for the 21 wells installed at the pump test site indicate the subsurface materials are fine-grained sandy silts and clays near the surface grading to relatively clean coarse sand and gravel with depth. The logs generally indicate a relatively distinct stratigraphic contact between the overlying fine-grained sediments and the underlying sand and gravel. The average depth below grade to the top of the sand and gravel deposit is about 35 feet. The sand and gravel deposit extends down to the top of bedrock (Denver Formation) which was encountered at an average of about 63 feet.

The average depth to groundwater as measured just prior to activating the pump for the drawdown test was about 37 feet. The boring logs indicate the water within the sand and gravel is primarily unconfined in the area of the test, although some confined conditions existed. The average saturated thickness of the sand and gravel is about 25 feet. The hydraulic gradient estimated from the water levels observed prior to the drawdown test, is approximately .002 ft/ft toward the northwest.

4.3.4.1.6 Data Analyses. When the pump was started, the water level in the pumped well fell about 12 feet in 30 seconds and remained at about this level throughout the 48-hour test. After 48 hours, drawdowns outside the well ranged from 2.2 feet at a distance of 5.5 feet from the pumped well to 0.6 feet at 410 feet. Aquifer characteristics for the alluvial aquifer were determined using the time-drawdown data for 17 of the 20 observation wells. Analyses using Boulton's method, assuming delayed yield for an unconfined aquifer, gave an average transmissivity value of 210,228 gpd/ft and an average specific yield of .085. Saturated thickness of the alluvial aquifer was usually within a foot of 25 feet for the observation wells prior to the pump test. Hydraulic conductivities calculated using the values for transmissivity and saturated thickness averaged about 1144 ft/day. The time-drawdown curves and calculations are included in Appendix A. Table 1 is a summary of the drawdown analyses.

TABLE 1

RESULTS OF DRAWDOWN ANALYSES USING BOULTON'S DELAYED-YIELD TYPE CURVES

WELL NO.	T (gpd/ft)	K (ft/day)	S
NW-3	169,765	908	.096
NW-2	229,183	1226	.051
NW-1	183,346	980	.145
SE-4	229,183	1226	.154
SE-3	254,648	1362	.055
SE-2	190,991	1021	.147
SE-1	241,245	1290	.054
669(27-045)	229,183	1226	.081
13-B	229,183	1226	.066
13-C	218,269	1167	.047
13-A	183,346	980	.097
14	163,702	1216**	.086
12-D	208,354	1114	.092
12-B	229,190	1226	.076
12-C	254,648	1362	.047
12-A	183,352	980	.071
12	176,294	943	.080
Averages	210,228	1144	.085

* Saturated thickness assumed equal to 25 feet.
** Saturated thickness equals 18 feet.

Recovery data was analyzed by Woodward-Clyde Consultants in accordance with methods presented in "Ground Water and Wells," Johnson 1975. The average values for the aquifer using the recovery data are:

Transmissivity = 285,000 gpd/ft

Hydraulic conductivity = 1,500 ft/day

These values are slightly higher than those obtained from the drawdown data. However, the recovery method may give a slightly high transmissivity in unconfined aquifers (Ground Water Manual, 1981).

4.3.4.2 Pump Test in Well W-5.

4.3.4.2.1 Well Installations and Development. Five 2-inch diameter PVC monitoring wells were installed in the vicinity of well No. W-5 for the purpose of monitoring ground water drawdown and recovery during the pump test. Existing monitor well 22-013 was also monitored during the test. The layout of the wells is shown in Figure 2. The pumped well (W-5) was a 6-inch diameter steel cased well with 5 feet of 6-inch diameter .090-inch slot wire-wound stainless steel well screen. Ten feet of 6-inch diameter steel pipe extended below the bottom of the screen into bedrock functioning as a sediment trap during development. The pumping well was installed with a Bucyrus-Erie churn drill. An 8-inch diameter hole was drilled to accommodate the 6-inch well. A 3/4-inch diameter PVC piezometer was installed inside the well for water level measurements. The well does not have an artificial gravel pack and was naturally developed with a surge block. Sediments were removed from the well with a sand bailer.

4.3.4.2.2 Drawdown Test. The drawdown test in well W-5 began at 12:11 p.m. on 6 December 1982. The well was pumped continuously for 48 hours. The initial discharge rate was 50 gpm. However, this rate quickly drew the water level to the pump intake (47.5 feet below top of casing). Several adjustments were necessary to sustain a consistent pumping rate. After the initial 90 minutes of the test, the well was pumped continuously at a rate of about 33.5 gpm ±6 percent. As a result, the early drawdowns during the test are not considered to be accurate. The aquifer characteristics determined from this test were determined by analyzing the late time drawdowns, when the pumping rate was relatively constant. The pumping rate was measured using a 5-gallon bucket and a stopwatch. The pumping rate was controlled by a gate valve located in the discharge line near the well. Discharged water was piped approximately 50 feet west-northwest from the discharging well. The pump was powered by a U. S. Army Corps of Engineers, Omaha District, portable diesel generator capable of supplying approximately 230 volts.

4.3.4.2.3 Water Level Data Acquisition. Water level measurements were initially taken at 1-minute intervals and gradually increased to every 2 hours after 10 hours and remained at 2-hour intervals for the duration of the test. Water level measurements were obtained using electric water level indicators. Initially, there was one water level indicator for each well. However, extreme cold overnight caused some of the batteries to fail. As a result, some instruments had to be used to measure more than one well.

4.3.4.2.4 Recovery Test. The recovery test began at approximately 12:11 p.m. on 8 December 1982, when the pump was shut off, and concluded 9 hours later. One additional measurement was made at 19 hours after shutdown. Water level measurements during recovery were taken at essentially the same intervals as during the drawdown test.

4.3.4.2.5 Aquifer Description. The subsurface materials in the vicinity of W-5 are primarily fat and lean clays near the surface grading into relatively clean sand and gravel with depth. There is a relatively distinct stratigraphic contact between the overlying fine-grained sediments and the underlying sand and gravel. The average depth below ground surface to the top of the sand and gravel is about 34 feet. The sand and gravel extends down to the top of the Denver Formation (weathered sandstone) which was encountered at about 42 feet. The average depth to groundwater just prior to activating the pump for the drawdown test was about 34.5 feet below ground level. The boring logs indicate the water within the sand and gravel is on the borderline of being confined or unconfined in the area of the test. The average saturated thickness at the time of the test was about 7.5 feet.

4.3.4.2.6 Data Analyses. When the pump was started, the water level in the pumped well dropped about 9 feet, and except during some flow adjustments, remained at about this level throughout the test. After 48 hours, drawdowns outside the well range from about 0.9 feet at a distance of 5 feet from the pumped well to about .45 feet at 47 feet. Aquifer characteristics for the alluvial aquifer were determined using the time-drawdown data from the observation wells. Drawdowns were plotted on log paper versus + and also r2/t for matching with the type curve for u versus W(u). The aquifer characteristics were determined from matching the observed drawdowns at late times with the type curve and solving for T and S using Theis equations. Early drawdowns were not considered because of the variation of pumping rates during the early portion of the test. Highly erratic measurements in P-3 and P-4 prevented analysis because they could not be matched to the curve. It is believed the erratic readings were the result of using different water level indicators and different personnel for measurements. Due to the small drawdowns during this test an effort was made to measure drawdown to the nearest .01 of a foot. Changing indicators coupled with different personnel taking the measurements can lead to errors in measurements of several hundredths of a foot. More continuity was achieved in measuring water levels in the other monitor wells; i.e., the same water level indicators were used in each well for the duration of the test and the same personnel took the measurements as much as possible. As a result, the drawdown curves were more uniform. The time-drawdown curves and calculations are included in Appendix ______. Table 2 is a summary of the drawdown and recovery analyses. Recovery data were also presented in Appendix ______. Recovery data were analyzed by plotting residual drawdown versus t/t' on semilog paper and solving for T and S in accordance with procedures outlined in U. S. Department of Interior, Ground Water Manual, 1981.

TABLE 2

SUMMARY OF DRAWDOWN AND RECOVERY ANALYSES

WELL NO.	T (gpd/ft)	K (ft/day)	S
	Drawdown (S vs. T)		
P-1	27,818	489	.64
P-2	38,388	693	.146
P-5	29,529	466	.175
22-13	45,700	848	.009
	Drawdown (S vs. r2/t)		
P-1	28,648	504	.68
P-2	42,653	770	.148
P-5	30,711	485	.187
22-13	41,726	774	.02
Drawdown Average	35,647	629	.25
	Recovery (s' vs. t/t')		
P-1	24,879	438	—
P-2	29,469	532	—
P-3*	23,265	420	—
P-4	28,519	508	—
P-5	29,469	465	—
22-13*	44,204	820	—
Recovery Average	29,967	530	
Total Average	33,213	587	

*Erratic recovery measurements - results questionable.

4.3.4.3 <u>Conclusions</u>. The pump test results indicate that the thin portion of the aquifer along the northeast half of the proposed containment system is only about half as permeable as the thick portion of the aquifer along the southwest half. The specific yield values from both tests indicate that the aquifer is unconfined.

4.3.4.4 <u>Well Efficiency Tests in Wells W-1 and W-3</u>. Wells W-1 and W-3 were installed to conduct well efficiency tests. The wells were installed under contract by Caissons Drilling, Inc. Both wells are constructed out of 12-inch diameter, schedule 80 PVC pipe, with slotted schedule 80 PVC pipe for screens. The screen length in both wells is 19 feet. The borings for the wells are 36 inches in diameter and were drilled with a 36-inch diameter auger. The annular space around the screens is backfilled with washed pea gravel. Five piezometers were installed in each well boring; one inside the well, one just outside the well casing, and three in the gravel pack. The two wells are essentially the same except for the slot size of the screens. W-1 had a .040-inch slot size with approximately 43 square inches of opening per linear foot of screen. W-3 had a .020-inch slot size with approximately 16 square inch of opening per linear foot of screen. Both wells were pumped at approximately 150 gpm and water levels monitored in the piezometers. W-3 could not sustain this pumping rate so it was reduced to 100 gpm. The basic conclusions from these tests was that W-3 was highly inefficient, even at the 100 gpm pumping rate. W-1 appeared to be fairly efficient at 150 gpm. The gravel pack appeared efficient, but only after development.

5. <u>GROUND WATER CONTAMINATION</u>.

5.1 <u>DBCP</u>. Chemical contamination of the alluvial aquifer ground water was investigated using ground water chemical analyses provided by RMA. For the purpose of developing contours of present contamination levels approximately 40 monitor wells were sampled and tested in the spring of 1982. Water samples were collected and tested by RMA personnel. Major emphasis was placed on developing contours representative of present contamination levels. Past data was not used in defining the DBCP plume. The DBCP plume enters the study area beneath the southeastern quarter of Section 27 where the plume follows the northwest-trending deep "gully" onto Bench II (see sheet C-16). Recent concentrations range up to 0.9 ppb in this area. Definition of the plume is complicated in the alluvium over Bench II due to the complex hydrology of narrow, thin, bifurcating possible flowpaths. The plume is recognized again flowing on the extreme eastern side of the large paleochannel. The plume "hugs" the boundary between the paleochannel and the unsaturated zone to the east. The plume is apparently pushed against the edge of the saturated alluvium by the north-northwestward ground water flow in the paleochannel. The plume flows in alluvium with a relatively low saturated thickness and maintains concentrations of up to 0.63 ppb. Any diffusion of the contaminant toward the deeper parts of the paleochannel may be diluted to less than 0.2 ppb by the influx of relatively uncontaminated water from the south. Thus, the plume is held to a relatively narrow band. The plume exits the arsenal in Section 22 by turning sharply to the northwest over Bench I. Concentrations at the boundary range up to 0.4 ppb. Past contamination levels in wells penetrating alluvium over Bench I reveal that there can be a wide lateral variation (1,000 foot) in the plume path at the boundary. However, records also imply that the plume path is relatively constant (except possibly as it travels over Bench II).

5.2 OTHER CONTAMINANTS. Chloride contamination closely follows the pattern for DBCP. Chloride concentrations of 700-1100 ppm correlate well with any DBCP concentrations above 0.2 ppb. Other areas in eastern Section 22 have anomalous chloride concentrations (800 ppm) which are not associated with high DBCP concentrations. The source of the chloride is probably the Basin "F" area. The contaminated ground water flows down off of Bench III into the small north-trending filled "gully" incised in Bench II beneath the eastern part of Sections 22 and 27. It follows this to its confluence with the large paleochannel near the boundary. Basin "F" also contributes chloride contamination to the ground water flowing westward over Bench II in the vicinity of the DBCP plume. DIMP and DCPD contamination levels in the study area are generally below maximum tolerance levels. Flouride contamination is widespread in the study area. Concentrations range up to 5.5 ppm. One source of flouride contamination is probably Basin "F." High concentrations (3-5.5 mg/l) extend down-gradient from Bench III in the area of Basin "F" to the large paleochannel via several paths over Benches II and I. High concentrations (72 ppm) of flouride in wells DH82-41 and 27-41 in the southern part of the study area may be associated with other sources.

6. CONTAINMENT SYSTEM.

6.1 CRITERIA. The containment/treatment system at the northwest boundary is designed to: (1) prevent off-post migration of ground water contaminated with DBCP above state drinking water standards (0.2ppb); (2) dishcarge ground water from the alluvial aquifer contaminated with DBCP (+0.2 ppb); (3) treat the water to remove DBCP to within drinking water standards; and (4) reinject the treated water with minimal disruption of the ground water flow off the arsenal.

6.2 Design Concept. Ground water containment will be achieved by constructing a combination hydraulic barrier/slurry cutoff wall across the portion of the aquifer where ground water contaminated with DBCP, in excess of 0.2 ppb, has historically and is presently migrating off the arsenal. The hydraulic barrier shall be constructed along the southwest half of the containment system where the aquifer is thick. The hydraulic barrier shall consist of two parallel lines of wells: one line of discharge wells; and one line of recharge wells. The bentonite slurry cutoff wall shall be constructed along the northeast half of the system where the aquifer is relatively thin. The discharge well line/slurry cutoff wall shall be located 800 feet inside and parallel to the northwest boundary, in the south half of Section 22. The line of recharge wells shall be located 200 feet inside the boundary, also in the south half of Section 22. Refer to sheet C-6 for location and layout of the containment system. Originally, the design concept for the containment system was a total hydraulic barrier. However, the thin saturated thickness and low permeability of the aquifer along the northeast half of the system made a hydraulic barrier, along this reach, economically and operationally undesirable. It was calculated that the maximum well spacing would be 50 feet, requiring at least 24 wells to

adequately dewater this 1,150-foot long reach. In addition, RMA criteria called for 1.2 recharge wells for each discharge well, thus requiring 29 recharge wells. This criteria was later relaxed. Operation of a system containing so many wells would be quite complex. Water levels would have to be monitored daily, balancing the flows to maintain ground water gradient reversal would require numerous adjustments, and seasonal changes in ground water levels would require total system adjustment. Also, considerable maintenance could be expected because of the number of pumps and wells involved. Because of the high cost and complex operation for all these wells, a decision was made to investigate the possibility and costs of containing the ground water flow in the thin aquifer with a slurry trench cutoff wall instead of wells. A cost estimate was prepared for a combined hydraulic barrier/slurry trench cutoff wall system and found the cost to be compatible with a total hydraulic barrier. As a result, the slurry trench cutoff wall was selected to contain the ground water flow in the thin aquifer because it offers several advantages over the hydraulic barrier. Advantages of the slurry trench cutoff wall are:

6.2.1 Less maintenance time and costs, due to the reduced number of wells and pumps. Less shut down time for well maintenance.

6.2.2 Assures positive cutoff in an area with complex hydrology.

6.2.3 Less complex operation.

6.2.4 Seasonal variations in ground water level will have less effect on system operation.

6.2.5 Less operating cost.

In order to assure the DBCP plume is entirely intercepted, a 2,350-foot long system is required. The dishcarge line/slurry cutoff wall shall consist of a 900-foot long reach of wells and a 1,425-foot long slurry wall. The recharge line shall consist of 21 wells along a 2,090-foot long reach.

6.3 <u>Site Selection</u>. Originally there were several proposed locations for the containment system. As the drilling program progressed, it became apparent that more favorable subsurface conditions exist closer to the boundary. Moving northwest, away from the bedrock bench situated approximately 1,600 feet inside and roughly parallel to the boundary, the geology and hydrology is more conducive to operation of the containment system. There is greater saturated thickness and less bedrock influence on ground water flow. Therefore, the final containment system location is as close to the boundary as practical. This location provides several advantages over any other site considered. Some of the advantages are as follows:

6.3.1 Ground water flow in this area is nearly perpendicular to the boundary and the containment system. This allows the DBCP plume to be intercepted with a shorter system. Review of the ground water and bedrock

plans indicates that a system located further inside the boundary would be nearly parallel to the ground water flow and the plume. This would require the system to be an additional 1,000 feet in length to assure the entire plume is intercepted.

6.3.2 The saturated thickness increases closer to the boundary. As a result, the length of the slurry cutoff wall is less, because there is less thin aquifer to cutoff.

6.3.3 There is a fairly extensive network of existing monitoring wells in this area. These wells can be used to monitor the system, eliminating the need to construct new monitor wells. There is a row of monitor wells along the boundary that can be used to monitor water quality and levels down-gradient of the recharge line. There is also a row of monitor wells that fall approximately mid-way between the discharge line/ slurry wall and the recharge line. These will provide water quality and levels within the system. Several monitor wells are located up-gradient of the dishcarge line/slurry wall to provide ground water data prior to entering the containment system.

6.3.4 Contains more contaminated ground water initially. By moving the barrier close to the boundary, there is less contaminated ground water between the system and the boundary to flow off the arsenal after startup.

6.3.5 The bedrock high in the vicinity of boring DH82-8A provides a place to tie the northeast end of the cutoff wall into.

6.3.6 Low ground water gradient. Reversal can be achieved with minimum drawdown and mounding.

6.3.7 Good contaminant data because of all the monitoring wells in this area.

6.4. <u>COMPUTER MODEL</u>. A finite-difference computer model simulating ground water flow in the Northwest Boundary Area and the effects of different pumping schemes was developed under contract by Woodward-Clyde Consultants. Details concerning the computer model are presented in Woodward-Clyde Consultants' report "Ground Water Modeling Phase 2, Northwest Boundary Containment System, PN-37," Rocky Mountain Arsenal, Denver, Co., August, 1982. This model was later modified by the Omaha District Corps of Engineers to simulate a combination hydraulic barrier/slurry cutoff wall system. The model was used to support the design of the containment system. Details on the model including different simulations can be found in Appendix _____.

6.5. <u>HYDRAULIC BARRIER</u>.

6.5.1 <u>Criteria</u>.

6.5.1.1 Develop a 900-foot long hydraulic barrier to contain ground water flow through the thick portion of the alluvial aquifer and to intercept any flow originating upgradient of the slurry cutoff wall.

6.5.1.2 A hydraulic barrier shall be achieved by constructing a line of discharge wells and a line of recharge wells. The ground water shall be discharged through the line of discharge wells, piped through a treatment building to remove organic contaminants to within state water standards, and injected back into the aquifer the line of recharge wells.

6.5.1.3 The hydraulic barrier will extend southwest from the end of the slurry cutoff wall to a point in the aquifer that historically had DBCP levels below state water standards.

6.5.2 <u>Design</u>. The design of the Northwest Boundary hydraulic barrier is based on the hydrologic characteristics of the alluvial aquifer. A barrier shall be achieved by discharging and injecting sufficient quantities of water to reverse the ground water gradient (flow) between the two well lines, thereby preventing any migration of contaminants off the arsenal.

6.5.2.1 <u>Length</u>. The proposed length of the hydraulic barrier is 900 feet. This length was determined by locating the DBCP plume (see sheet C-16) and extending the line of wells a sufficient distance to either side of the plume to assure the entire plume is intercepted. Also, the aquifer thickness along the discharge line was determined so wells could be located in areas that have sufficient saturated thickness to assure adequate pumping rates can be sustained.

6.5.2.2 <u>Well Line Spacing</u>. The selected distance between the discharge and recharge well lines is 600 feet. Based a ground water gradient across the system of .003 ft./ft., the head between the well lines drops 1.8 feet. This is the maximum head difference that must be overcome to achieve gradient reversal. Well line spacing greater than 600 feet increases the head differences thereby requiring substantially higher pumping rates to achieve reversal. Well line spacing closer than 600 feet increases recirculation to an undesirable percentage. Computer modeling of various well line spacings confirms that 600 feet between the well lines is the most efficient system. For more detailed information concerning well line spacing and recirculation refer to Woodward-Clyde Consultants' report "Ground Water Modeling Phase 2, Northwest Boundary Containment System, PN-37," August 1982. The distance between well lines is also an important factor for the period of time the entire system can be shut down before contaminants pass through the system. The calculated shutdown times for the 600 foot well line spacing is as follows:

Continuous Pumping Period Prior to Shutdown (days)	Maximum Allowable Down Time (days)
7	0
30	0
96	17
180	69
365	69

6.5.2.3 **Well Depths.** Discharge and recharge well depths were determined by interpreting bedrock-alluvium contacts from exploratory borings. Discharge wells shall be drilled through the alluvium and 10 feet into bedrock. Discharge well depths will vary from approximately 70 feet to approximately 54 feet. Recharge wells will be drilled through the alluvium and 5 feet into bedrock. Recharge well depths will vary between approximately 60 and 48 feet.

6.5.2.4 **Well Spacing.** The discharge wells will be spaced every 100-feet. A 100-foot spacing was selected for two reasons, (1) sufficient drawdown can be achieved midway between the wells at moderate pumping rates; and (2) this spacing insures no contaminant leakage occurs in the event of a single pump outage. If a pump outage does occur, the pumping rates in adjacent wells can be increased to prevent contaminant leakage. Although greater well spacing and higher pumping rates may provide the necessary drawdown, it will be difficult to sustain these higher pumping rates. Additionally, in the event of a single pump outage, the greater gap between pumping wells will provide a path for contaminant leakage. Based on RMA criteria, 1.2 recharge wells shall be provided for each discharge well. The recharge wells shall be spaced every 80 feet. This spacing allows for the recharge line (with the 1.2 recharge/discharge ratio) to occupy approximately the same lateral distance as the discharge line.

6.5.2.5 **Pumping Rates.** The startup pumping rate for the hydraulic barrier shall be 100 gpm per well, or 1,000 gpm for the total discharge line. This rate was established by calculating the amount of drawdown necessary to reverse the ground water gradient between the two lines of wells. As indicated previously, the head difference between the two well lines is approximately 1.8 feet. Therefore, drawdown along the discharge line and mounding along the recharge line must combine to exceed 1.8 feet. However, to provide a safety factor it is desirable to attain the necessary reversal in gradient solely by drawdown along the discharge line. For this reason, a pumping rate that will provide at least 1.8 feet of drawdown between discharge wells was the selected design criteria. Drawdowns along the discharge line were calculated using the Muskat equation for a well discharging from an aquifer bounded by a finite line source as presented in USGS Water Supply Paper 1545-C, 1963, "Shortcuts and Special Problems in Aquifer Tests." The Muskat equation for a finite line source was selected because it closely resembles the actual conditions once the hydraulic barrier

is in operation, i.e., the recharge line represents a finite line source. Using 100 gpm discharge rate for each well, drawdown vs. distance for each well was determined. After calculating total well inference, drawdowns in excess of 2-feet can be expected mid-way between discharge wells. See Appendix _____ for calculations using the Muskat equation. This amount of drawdown, combined with mounding along the recharge line, will provide a sufficient safety factor (SF = 1.6) in the system design. Computer modeling indicates mounding along the recharge line will be about 1 foot. Treated water will be divided equally among the recharge wells, which equals approximately 80 gpm per well. Computer modeling and hand calculations indicate this system will function satisfactorily with these pumping rates. After system startup, if field monitoring indicates results different from design calculations, adjustments in pumping rates can be made. Since the discharge rates may have to be adjusted during operation, each well pump is designed to have a discharge capability of ±30 percent of the design value of the well. Pumping flexibility will also allow for increasing individual pumping rates in the event of a pump shutdown for maintenance or failure or for increasing the pumping rate of the entire system if the water table rises.

6.5.3 Well Construction and Materials. Screen lengths and placements, and well depths were determined by constructing geologic profiles along the dewatering and recharge alignments and interpreting bedrock contacts and aquifer thickness from adjacent boreholes. Screen slot size and gravel pack gradation were determined from the grain size distribution of the aquifer material. Grain size analyses are presented in Appendix _____. Well details are presented on sheet C-17.

6.5.3.1 Discharge Wells. Discharge wells shall be 8 inches in diameter. The casing and tail pipe shall be constructed of black steel, with a wall thickness of 0.33 inch. The screen shall be manufactured entirely from stainless steel. Well screens shall be the continuous slot wire wound, nonclogging type with a .080-inch slot size. Stainless steel is selected because of its high strength and corrosion resistance. The screens shall be the continuous slot wire wound type, because this design offers the maximum open area per linear foot of screen length. The nonclogging type slot (widening inward) is essential to minimize clogging during development and pumping. The continuous slot wire wound design coupled with the nonclogging type slot will result in the most efficient well. Boreholes for the construction of dewatering wells will be 16 to 18 inches in diameter, which allows for a 3-1/2 to 4-1/2-inch gravel pack around the screen. The holes shall be drilled eleven (11) feet into bedrock. The bedrock portion of the hole shall be cased to act as a tailpipe. Discharge wells shall be screened from 1-foot below top of bedrock to about 2 feet below the top of the sand and gravel aquifer.

6.5.3.2 __Recharge Wells__. Recharge wells shall be 12 inches in diameter. They shall be constructed with black steel casings and stainless steel continuous slot wire wound, nonclogging screens, with .080-inch slot size. The boreholes for construction of the recharge wells shall be 24 inches in diameter, allowing room for a 5-1/2-inch thick gravel pack around the screen. Holes shall be drilled 5 feet into bedrock with that portion of the hole cased to provided a tailpipe. Recharge wells shall be screened for nearly the entire thickness of the alluvial aquifer, regardless of the thickness of the saturated zone. Unsaturated screened portions may present development problems. It is anticipated that jetting with water will be necessary for developing the portions of the screens above the saturated zone.

6.5.3.3 __Tailpipes__. Tailpipes are included in the design of both the recharge and discharge wells, because this allows for full development of the screen and the screened portion of the aquifer. This is especially important in the zone just above the bedrock-alluvium contact because this is often the most permeable zone of the alluvial aquifer. The tailpipes in the discharge wells are longer because they will also serve as the pump housing.

6.5.3.4 __Drilling__. All wells shall be drilled by the reverse rotary method. Only water will be used as the drilling fluid. Bentonite will not be permitted. Water used for drilling shall be clean and uncontaminated. RMA personnel indicate a clean water source is available near Basin F from a 2-inch water supply line.

6.5.3.5 __Gravel Pack Design__. Sieve analyses were run on representative samples of the aquifer material taken from the borings drilled along the proposed alinement of the recharge and discharge lines. Fifty samples from 22 borings were analyzed. The Soil Classification Record Sheets showing the laboratory classification of all the samples are in Appendix A. Gradation curve analyses were made on representative samples by the MRD Laboratory. These results are shown on the Soil Classification Record Sheets. Gradation curves for the remaining samples are in Appendix A.

Due to the large number of gravel packed wells, an average gravel pack material had to be chosen. The average 30 percent (passing) size was determined from all the samples to be 0.56 millimeters (mm). This number was multiplied by 5 to determine a 30 percent size for the gravel pack. A smooth curve with a uniformity coefficient of two was drawn through the 30 percent size plotted on a gradation curve graph. Sieve sizes were picked to cover the spread of the curve and a range of 8 percent above and below the percent passed at each sieve size point was chosen.

The slot size for the screen 0.080 inches (80 slot), was chosen to pass only 10 percent of the gravel pack material. The calculations and graphs are in Appendix _____. The gradation of the gravel pack is as follows:

U.S. Sieve Size	% Passing
3/8"	100
4	87-100
6	67-83
8	7-23
10	0-15

In Ground water and Wells by Johnson Division, UOP Inc., it is suggested that in highly nonuniform formations with silt, such as that at RMA, the 30 percent size should be multiplied by 6 and by 9 to obtain two curves with low uniformity coefficients, and the gravel pack material is chosen from between these two curves. However, in this case, where one gravel pack was chosen for a large number of wells, a slightly more conservative approach, as described before, was taken.

Colorado Silica Sand has indicated that they would be able to provide a gravel pack with the following gradaton:

Sieve Size	% Passing
3/8	100
4	90-100
6	70- 85
8	10- 20
10	0- 10

6.5.3.6 **Disinfection.** All wells shall be thoroughly disinfected upon completion. Disinfection shall be accomplished in such a manner to insure a 1,000 ppm available chlorine solution is uniformly applied throughout the entire depth of the well.

6.6. SLURRY TRENCH CUTOFF WALL.

6.6.1 Criteria

6.6.1.1 Develop a 1,425 foot long slurry-cutoff wall to provide an impermeable barrier which will prevent ground water migration through the thin portion of the alluvial aquifer.

6.6.1.2 The trench for the cutoff wall will be excavated through the alluvial aquifer and into the Denver Formation (bedrock). The trench will also be excavated through any Denver sandstone units in contact with the overlying alluvium.

6.6.1.3 The cutoff wall will be constructed by excavating a bentonite slurry trench which will be backfilled with a mixture of select backfill and bentonite.

6.6.1.4 Several discharge wells will be placed upgradient from the wall to prevent excessive head build-up.

6.6.1.5 Several recharge wells will be placed downgradient from the wall to maintain uninterrupted ground water flow off the arsenal and to prevent excessive head differences across the wall.

6.6.1.6 The cutoff wall will tie into a bedrock high on the northeast end. The southwest end will be open-ended, directing ground water flow to the discharge well line.

6.6.2 Design. The design of the Northwest Boundary slurry cutoff wall is primarily based on the slurry wall at the north boundary. The satisfactory performance of the north boundary slurry wall indicates it was suitably designed and constructed for the subsurface conditions encountered at the arsenal. The cutoff wall will be constructed by excavating a bentonite slurry trench which will be backfilled with suitable material mixed with bentonite clay to form a near impermeable barrier through the alluvium and into the Denver Formation. The cutoff wall will penetrate shallow Denver sandstones in contact with the alluvial aquifer at the barrier. Additionally, the cutoff wall will penetrate weathered, fractured shales to prevent fracture flow under the wall. Any sandstone units encountered below the alluvium will be removed. One such sandstone unit is known to exist in the vicinity of well number W-5. This unit is approximately 10-feet thick. The slurry trench depth has been determined by constructing a geologic profile along the trench alignment and interpreting bedrock contacts and alluvium thickness from adjacent boreholes. Based on this profile, the average depth of the trench will be approximately 52-feet, with a maximum depth of about 60 feet and a minimum depth of about 40 feet.

6.6.2.1 Length. The length of the slurry cutoff wall is 1,425 feet. This length is designed to cut off the aquifer in the area where the saturated thickness is less than 10-feet. The northeast end is fixed because of the bedrock high in the vicinity of boring DH82-8A. The southwest end terminates at a location where the saturated thickness exceeds 10-feet.

6.6.2.2 Width. The minimum width of the slurry cutoff trench will be 30 inches. This width was selected for the following reasons: (1) 30-inch width is functioning saisfactorily along the north boundary; (2) sufficient width to assure proper backfilling, minimizing bridging potential; (3) provides adequate bedrock contact to minimize underseepage; and (4) is a common trench width, so specialized excavating equipment is not necessary.

6.6.2.3 Depth. To assure the trench bottom is in relatively unfractured and unweathered shale, the minimum excavation depth shall be 5-feet below top of shale. The final depth will be based on field inspection of undisturbed samples taken periodically along the trench bottom.

6.6.2.4 Slurry. The slurry used in the trench shall consist of a uniform mixture of high swelling sodium base bentonite and water.

6.6.2.5 Backfill. Backfill material before blending shall conform to the following gradation:

Screen Size or Number (U.S. Standard)	Percent Passing by Dry Weight
1-1/2-inch	100
3/4-inch	80-100
No. 4	50-100
No. 30	25- 70
No. 200	10- 35

Blended backfill material shall be composed of bentonite slurry and suitable backfill material thoroughly blended. It shall have an in-place permeability of approximately 10' cm/sec.

6.6.2.6 Bentonite. Bentonite used is the slurry and backfill shall be an ultrafine sodium cation-base montmorillonite powder (Wyoming-type bentonite).

6.6.3 Construction.

6.6.3.1 Excavation. The trench shall be excavated to the full depth and width in one continuous segment. Excavation shall start at one end and contimue to the other end so that when completed, provides a continuous 30-inch wide trench to the required depth. Bentonite slurry shall be introduced into the trench at the time excavation begins. The level of the slurry in the open trench shall be maintained within 1 foot of the top of the trench. Most of the material to be excavated from the trench is either fat or lean clay. Clay is not a suitable backfill material because it is nearly impossible to mix with the bentonite slurry. Since most of the material that will be excavated will not be unsuitable for backfill, all excavated materials shall be spoiled in an approved spoil area. It is not cost effective to try to salvage the small quantities of material that may meet the backfill gradation. The sandstone unit encountered in the vicinity of well number W-5 is most likely too hard to be excavated with a backhoe or dragline. It is anticipated that light blasting or some mechanical means will be required to break the rock prior to excavation.

6.6.3.2 Backfilling. Backfill shall be placed continuously from the beginning of the trench in the direction of excavation to the end of the trench. Free dropping of backfill shall not be permitted. It shall be placed by lowering it to the bottom of the trench or by sliding it down a previously formed slope. Backfilling operations shall lag the trench excavation by a minimum of 30 feet, but not more than 100 feet. Backfill material will be obtained from borrow areas. Calculations indicate approximately 7,000 cubic yards of borrow will be required. Investigations are presently underway to locate suitable borrow areas on the arsenal. This will be completed prior to advertising the contract. If a suitable borrow cannot be located on the arsenal, then borrow material will have to be obtained off the arsenal.

6.6.4 **Discharge and Recharge Wells Adjacent to the Slurry Cutoff Wall.**

6.6.4.1 **Discharge Wells.** Five discharge wells shall be situated 50 feet upgradient from the cutoff wall to prevent excessive head buildup along the wall. The well spacing varies, refer to the location plan. The start up pumping rate is 25 gpm per well, which should closely equal the ground water flux through this area. These wells will be constructed in the same manner and dimensions as the discharge wells along the hydraulic barrier portion of the containment system.

6.6.4.2 **Recharge Wells.** Eight recharge wells will be situated 600 feet down gradient of the cutoff wall, in line with the hydraulic barrier recharge wells. These will be spaced every 150 feet. The function of these recharge wells is to maintain ground water flow off the arsenal and to prevent excessive head differences across the wall. The 125 gpm discharged upgradient of the cutoff wall will be proportioned evenly among the eight recharge wells requiring each well to inject about 15 gpm. These recharge wells shall be constructed in the same manner and dimensions as the recharge wells along the hydraulic barrier portion of the containment system.

6.6.4.3 Like the hydraulic barrier wells, discharge and recharge rates may have to be adjusted to meet field conditions. For this reason, these discharge wells will also have a discharge capability of ± 50 percent of the design value of the well.

7. NORTHWEST BOUNDARY MONITORING SYSTEM CRITERIA.

7.1 Monitoring of water quality and water levels is required to check the effectiveness of the Northwest Boundary Containment/Treatment system and to provide data for discharge, treatment, and recharge operations. Monitoring is required both onpost and offpost in the Northwest Boundary area.

7.2 Periodic water quality data are needed to determine the extent of contamination and concentration levels flowing to the containment system from upgradient. Similarly, these data are needed downgradient to establish system effectiveness.

7.3 Periodic water level data are needed to demonstrate the degree to which the natural flow regime is disturbed by barrier operation, both upgradient and downgradient of the barrier. Detailed water level monitoring is needed within and around the containment system to determine if the barrier is functioning properly. A system of piezometers will be installed to serve this function.

7.4 Water quality in the aquifer above the bedrock high to the north of the barrier needs to be monitored to assure no contaminant is passing by the system.

8. MONITORING WELLS.

8.1 Onpost. Essentially no new monitor wells are proposed to monitor the containment system. There are sufficient existing wells to adequately monitor contaminant concentrations within, upgradient and downgradient of the containment system. Any monitoring wells removed or damaged during construction will be replaced. Replacement wells will be constructed as near as possible to the abondoned well. Replacement wells will be constructed in a similar manner and with similar materials as the original wells. Two new monitoring wells are proposed to monitor ground water quality in the alluvium above the bedrock high to the north of the system. The exact locations of these wells have not been selected as of this writing, but will be included in the contract documents. Monitor wells will be constructed of 4-inch diameter, schedule 80 PVC pipe with treaded couplings. Screens will be slotted (.040-inch slot) PVC schedule 80 pipe. Drilling these wells will be in accordance with the drilling procedures specified for all discharge wells. Except for the upper 10-feet, the annulus around the PVC pipe and screen will be backfilled with a sand and gravel formation stabilizer. The upper 10-feet of the annular space will be filled with a neat cement grout to form a seal against infiltration of surface water.

8.2 Offpost Monitoring Wells. Eight offpost monitor wells are proposed to monitor the effect of the containment/treatment system on the ground water flow and quality off the arsenal. For this reason, these wells should be installed prior to construction of the slurry cutoff wall and start-up of the system. The proposed well locations are along state and county road right-of-ways to avoid obtaining rights-of-entry to private property. The proposed locations are shown in figure 3. Offpost monitor wells shall be constructed of the same materials and in the same manner as the onpost monitoring wells with the following exceptions: The holes shall be drilled utilizing churn drilling methods so no drilling fluid is required; and a protective steel casing with a locking cap will be installed around the PVC pipe stickup.

8.3 Piezometers. Sixteen piezometers will be installed within the containment system, for the purpose of monitoring water levels to assure the system is functioning as planned. Piezometers shall be constructed of 2-inch

diameter schedule 80 PVC pipe with treaded couplings. The locations of the piezometers are shown on sheets C-7 through C-11. For details, refer to plate C-17, "Well and Piezometer Details." Piezometers were located periodically along the discharge line, the recharge line, and on both sides of the slurry cutoff wall. They are placed in such a fashion that when they are read, together with existing monitoring wells, will provide an accurate profile of the ground water gradient throughout the system. Examination of the gradient within the system will show how well the system is functioning and provide data for system adjustments. The holes for the piezometers shall be drilled with a hollow stem auger of sufficient diameter to allow proper placement of the instrument, formation stabilizer, and grout seal. Since no glue is being used, these piezometers can also be used as monitoring wells if needed.

CHAPTER II - SANITARY

1. **GENERAL PARAMETERS.**

1.1 **PURPOSE, FUNCTION, AND CAPACITIES OF THE FACILITY.** The purpose of the facility was to remove Nemagon (DBCP) contamination from the ground water crossing Rocky Mountain Arsenal without altering the flow beyond the Arsenal boundary. Ground water is pumped from a row of 15 discharge wells, treated by carbon absorption, and returned through recharge wells to the aquifer. The estimated ground water flux at the hydraulic barrier was 1,500 gallons per minute at maximum water level. The design of the pumps, piping, and treatment system was based on a peak flow of 1,500 gallons per minute.

1.2 Personnel is shared by this facility, the North Boundary project, the Lake "F" project, and other similar pollution abatement systems.

1.3 The utilities required for support of the treatment building were included in this design. A new power supply was brought in from outside the Arsenal. Standby power was required. Potable waterlines were connected to the Arsenal system near Lake "F." Domestic sewage is treated by a septic tank-absorption field system.

2. **FUNCTIONAL AND TECHNICAL REQUIREMENTS.**

2.1 **Dewatering and Recharge System.**

2.1.1 Design capacity of the dewatering system, the treatment system, and the recharge system must be equal to the maximum contaminated water flux at the barrier with allowances for extraneous flows and recirculation. The estimated capacity was 1,500 gallons per minute.

2.1.2 The dewatering system consists of 15 discharge wells with the discharge piping from each well connected to a common header. Each well contains a vertical submersible pump. The pumps for discharge wells (DW) 1 through 10, were designed for a maximum and average flow of 135 and 100 gallons per minute respectively, while the pumps for DW 11 through DW 15 were designed for a maximum and average flow of 30 and 25 gallons per minute. Control of discharge well pumping consists of automatic stop and start on water level. A high water level alarm, consisting of a red light on each well control stand, was provided to indicate a high water level condition due to pump failure. A valve pit located near each well contains a manually controlled back pressure valve, to control the rate of pumping from each well, and a flow meter that indicates and totalizes the flow pumped from each well. A shutoff valve on each well discharge line will isolate the well and valve pit from the rest of the dewatering system.

2.1.3 Contaminated water pumped from the discharge wells flows into the influent sump from where it is pumped into the treatment building. Treated water is discharged into the effluent sump and from there it is

pumped into the recharge wells. The influent and effluent pumping systems consist of a set of four 500 gallon per minute pumps in each sump. The sump pumps operate in parallel and are controlled by the water level in the sumps. The operation of three 500 gpm parallel pumps in each sump allows operation of the treatment facility at the maximum, average and minimum anticipated flow rates. The fourth pump in each set was provided for standby operation. Automatic start upon pump failure and manual alternation was provided.

2.1.4 Treated water from the effluent sump is carried through a recharge header pipe to the recharge system. The recharge system consists of a row of 21 recharge wells. A valve pit and a shutoff valve were provided for each well. The valve pit contains a V-port ball valve to control the flow of treated water to each of the wells. Valve settings are manually adjustable and should be changed for seasonal conditions. A flow meter was also included in each valve pit to indicate and totalize the flow into each well. A water level recorder was provided near each well to monitor and record changes in water level. A high water level alarm consisting of a red light on the well recorder stand was also provided. It indicates the need to manually shutoff the well. A shutoff valve at each recharge well influent line isolates the well and valve pit from the rest of the recharge system.

2.2 SUPPORT UTILITIES.

2.2.1 Potable water was required to service the new treatment building. A new 2-inch potable waterline was connected to the Arsenal system, near Lake "F." A line ±8,000 feet long was required. Head losses due to pipe friction exceeded the head regained due to differences in elevation. A hydropneumatic tank, was provided inside the treatment building for water storage and pressure increases. The hydropneumatic was not included in this design.

2.2.2 Domestic sewage from the treatment building is treated by a septic tank-absorption field system. Sewage from the treatment building is conveyed by gravity to a 500 gallon septic tank for treatment. Effluent from the tank discharges to an absorption field system for further treatment and infiltration into the ground.

2.2.3 Materials and Equipment. Flow meters in the valve pits displacement type requiring no electrical connections. Pipe and valves inside the valve pits are metallic. Plastic pipe was used for all buried pipe to reduce pumping cost and scale problems.

2.2.4 Pipe Cover. All pressure piping was provided with a minimum cover depth of 5 feet from the finished grade to the top of the pipe to prevent freezing.

3. DESIGN OBJECTIVES AND PROVISIONS.

3.1 The travel time of contaminated water toward the boundary is slow, approximately 3 feet per day. Anticipated maximum duration of any power outages would be less than a week; with contaminated water travel in the magnitude of 10 feet. Most power interruptions are less than an hour. Water levels in the sumps would be static without a power supply. Controls and water meters would not be affected by a loss of power. Standby power was not considered to be necessary.

3.2 The major pumping equipment in the sumps consists of four influent pumps in parallel and four effluent pumps in parallel. All of these pumps have equal flow capacity, but the influent and effluent head requirements differ. Three pumps will handle the maximum flow on either influent or effluent side. Only one pump is required on each side under low flow conditions. At least one pump will be spare on each side under any ground water conditions.

3.3 The dewatering system does not have standby equipment installed. Suitable spare pumps were provided to allow quick replacement of any discharge pump. Manual adjustment of the back pressure valves for the two adjacent wells will allow those wells to compensate for the out-of-service well on a temporary basis. All wells were designed for continuous pumping during high ground water conditions to achieve a stable hydraulic gradient. At lower ground water levels, wells can pump continuously at lower rates. Some of the wells can be taken out of service during sustained low water level conditions.

3.4 Control of the flow pattern requires manual adjustment of control valves at every discharge well and recharge well. Pressure in the transmission lines will be maintained at a pressure adequate to provide control of waterflow at each well regardless of differences in elevation. The wells span an elevation differential of approximately 30 feet.

4. CALCULATIONS. See Appendix C.

CHAPTER III - ELECTRICAL

1. **GENERAL PARAMETERS**. This design is based on, but not limited to the following publications, codes, specifications, etc.

1.1 National Electrical Code NFPA No. 70.

1.2 Life Safety Code NFPA No. 101.

1.3 National Electrical Safety Code (ANSI) C2-1973 (The above code C2-1973, replaced Handbooks H30 and 81).

1.4 Department of Defense Construction Criteria Manual DOD 4270.1.

1.5 Project Development Booklet (PDB).

1.6 Criteria furnished by Using Service.

2. **SCOPE**. This design will generally consist of the following details:

2.1 **INTERIOR OF SUMP AND VALVE HOUSINGS**.

2.1.1 Raceway systems and conductors.

2.1.2 Power systems for special equipment and standard receptacles.

2.2 **EXTERIOR**.

2.2.1 Primary overhead and underground distribution.

2.2.2 Secondary overhead and underground.

3. **INTERIOR WORK**.

3.1 **RACEWAY SYSTEM** will be as follows:

3.1.1 Intermediate Metal Conduit. (IMC)

3.1.2 Electric Metallic Tubing (EMT).

3.1.3 Rigid Metal Conduit (Heavy Wall).

3.1.4 Wireways.

3.2 **CONDUCTORS** design will be based on copper.

3.2.1 Conductor identification in multiphase systems serving single-phase loads shall be color coded. The color of the insulation of the ungrounded conductors of different voltage systems shall be as follows:

277/480 volt, 3-phase: yellow, brown, and orange;
120/240 volt, single phase: red and black.

Color coding is not required for 3-phase loads.

3.2.2 Wire size based on 75° C Ampacity Column.

3.3 Receptacles will be as follows:

Note: See Standard Legend Sheet for receptacle description.

3.3.1 Grounding Type 15 Ampere, 125 volt, three-wire.

3.4 Wall switches will be rated 120 volt 15 ampere.

3.5 Service equipment and disconnecting means shall be of the fusible switch type.

3.6 Underground service to the wells will be provided.

3.7 Ground Fault Circuit Interrupters (Personnel Protection See NEC 210-8) will be provided as follows:

3.7.1 Receptacles in wet locations.

3.8 Electric Heat will be of the following type:

3.8.1 Strip Heaters.

4. EXTERIOR ELECTRICAL.

4.1 The distribution system will consist of a new three phase aerial extension from the existing 12470Y/7200, line at the indicated location. Public Service Co. will install a primary metering pole. Cost to contractor will be approximately $3,000.00.

4.2 The complete exterior system shall include the following material and equipment.

4.2.1 Transformers.

4.2.1.1 Single phase for wells and three phase for building.

4.2.1.2 Cluster or radial bracket and pad mounted.

4.2.2 Aerial Line conductor.

4.2.2.1 Primary.

4.2.2.2 Size #6.

4.2.2.3 Type ACSR.

4.2.3 Underground conductors.

4.2.3.1 Primary in duct.

4.2.3.2 Size #2.

4.2.3.3 Cross-linked polyethylene with polyvinyl jacket.

4.2.3.4 Cross-linked polyethylene with polyethylene jacket.

4.2.4 Secondary conductors.

4.2.4.1 Underground - USE.

4.2.4.2 Aerial polyethylene.

4.2.4.3 Voltage 120/240 and 480/277.

4.2.5 Surge arresters.

4.2.6 Down guys and anchors.

4.2.7 Insulators.

4.2.8 Potheads, resin terminations, taped terminations, positive pressure sealed type terminations.

4.2.9 Duct banks.

4.2.9.1 Primary.

4.2.9.2 Rigid Steel Conduit.

4.2.9.3 Without encasement.

4.2.10 Primary fuse cutouts.

4.3 Cathodic protection will not be provided.

4.4 Attached calculations show pole sizes, transformer sizes, and voltage drop.

5. Building was designed by Architect-Engineer.

6. CALCULATIONS.

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT Northwest Boundary Containment		SHEET NO. 1 OF 9
ITEM Elec. Calculations		BY KER DATE 2/4/93
		CHKD. BY DATE

Major Load Summary

De-Watering Wells

			Elec. Heat	& Controls
DW1 -	5 h.p	&	500 Watts	& 100 W
DW2 -	5 h.p.	"	" "	"
DW3 -	5. h.p.	"	" "	"
DW4 -	5. h.p.	"	" "	"
DW5 -	5 h.p.	"	" "	"
DW6 -	5 h.p.	"	" "	"
DW7 -	5 h.p.	"	" "	"
DW8 -	5 h.p.	"	" "	"
DW9 -	5 h.p.	"	" "	"
DW10 -	5 h.p	"	" "	"
DW11 -	5 h.p.	"	" "	"
DW12 -	1½ h.p.	"	" "	"
DW13 -	1½ h.p.	"	" "	"
DW14 -	1½ h.p.	"	" "	"
DW15 -	1½ h.p.	"	" "	"

Re Charge Wells - no pumps

controls & Electric Heat

RW1 -	500 Watts	RW20 -	500 Watts
RW2	" "	RW21 -	" "
RW3	" "		
RW4	" "		
RW5	" "		
RW6	" "		
RW7	" "		
RW8	" "		
RW9	" "		
RW10	" "		
RW11	" "		
RW12	" "		
RW13	" "		
RW14	" "		
RW15	" "		
RW16	" "		
RW17	" "		
RW18	" "		
RW19	" "		

OMAHA DISTRICT | COMPUTATION SHEET | CORPS OF ENGINEERS

PROJECT N.W. Boun. Cont. - R.M.A.		SHEET NO. 2	OF 9
ITEM		BY KEA	DATE 2/9/83
Elec. Calculations		CHKD. BY	DATE

De-Watering Wells - provide 1Ø 230/120V

		5 hp	1½ hp
pump	=	5152 watts	1840 watts
Heater	=	500 watts	
controls	=	100 watts	
		5752 watts	2440 watts

31 amps

use #6 aerial & dir. burial sec; use #8 to motor from Disconnect

40 Amp Fuse in Disconnect

* Size Transformers for DW1 thru DW11 assume 3 wells per trans.
3 x 5752 watts = 17256

use 7200/12470Y to 120/240, 1Ø
25 KVA transformers

* Size Transformers for DW12 thru DW15 assume 3 wells per trans.

3 x 2440 = 7320 watts

use 7200/12470Y to 120/240, 1Ø
10 KVA transformers

MRO FORM 1 OCT 72 1550

OMAHA DISTRICT | COMPUTATION SHEET | CORPS OF ENGINEERS

PROJECT N.W. Boun. Cont. - R.M.A.		SHEET NO. 3	OF 9
ITEM Electrical Calculations		BY KEA	DATE 2/1/83
		CHKD. BY	DATE

Load at Re-Charge Wells

R.C. 1 thru R.G. 21

500 watt heater
plus
100 watts controls

600 watts → 2.6 amps
use #10 aerial & direct buried secondary & #12 from d.s. to heater
assum 4 wells on each transformer

600 × 4 = 2400 watts

Use 7200/12470 to 120/240
1φ, 5 KVA transformer

MRO FORM 1550
1 OCT 72

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT N.W. Boon. Cont. - R.M.A.	SHEET NO. 4 OF 9	
ITEM Primary Line Design	BY SEA	DATE 2/4/83
	CHKD. BY	DATE

Line Design Criteria

TM5-765, para. 3.4 — 50% Growth Allowance

TM5-765, para. 12-2 - 175' max span

TM5-811-1, para 1-28 — 2% Primary Volt. Drop

Basic clearances - Horizontal construction

STD DWG 40-06-17, sheet 3.

≈ 150' span, 3' Assumed max load sag at ctr. of span; clearances shown at pole X-arm

	Primary	Neutral	Comm.	Sec.
Road	23'	21'	21'	21'
Elsewhere	18'	18'	18'	18'

Comm - Sec. - 4'
Comm - Neutral - 6'
Sec. - Neutral - 18"
Sec - Primary - 4'
Com - Primary - 6'

AEIM-8, page 5-15 - Comm. space shall be provided on all poles unless otherwise directed

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT N.W. Boun. Cont. - R.M.A.		SHEET NO. 5	OF 9
ITEM Primary Line Design		BY KEA	DATE 2/[illegible]/73
		CHKD. BY	DATE

Pole height calculations:

Design based on N & Pri. on same cross arm.

Poles with Comm. & Pri. only

<u>Road crossings</u>

Comm. - 21'
Comm - Pri. - 6'
} 27'

35' pole has 29' available

<u>use 35' poles</u>

<u>Elsewhere</u>

Comm - 18'
Comm - Pri. - 6'
} 24'

30' pole has 25'6" available

<u>use 30' poles</u>

Poles with Comm. - Sec. - Primary

<u>Elsewhere</u>

Comm. 18'
Comm - Sec. 4' 26'
Sec. - Pri. 4'

35' pole has 30' available

<u>use 35' poles.</u>

Due to limited # of 30' poles on job for simplicity use all <u>35' poles</u>

MRO FORM 1550
1 OCT 72

Page ______

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT N.W. Boun. Cont. - K M. A.	SHEET NO. 6 OF 9	
ITEM Primary Line Design	BY KEA	DATE 5/ /83
	CHKD. BY	DATE

Voltage Drop Calculation:

New Primary extension will feed the following loads:

1 - 300 KVA 3ø Trans. at Bldg.

4 - 25 KVA 1ø Trans. at Dewatering wells

1 - 10 KVA 1ø Trans at Dewatering wells

6 - 5 KVA 1ø Trans. at Re-changeovers

440 KVA total

allow for 50% expansion =: 660 KVA

design for 700 KVA, 12470Y/7200 V

Diversity = 1.2

$$I_{Demand} = \frac{700\ KVA}{(12470)(\sqrt{3})(1.2)} = \underline{\underline{27\ Amps}}$$

<u>Aerial Voltage Drop</u>

Pender - Delmar <u>Elect. Engr. Hdbk</u>

3rd Edition, page 14-20, Simple impedance method

$$\%\ Voltage\ Drop = 100\left[\sqrt{(\cos\theta + \frac{r}{Z})^2 + (\sin\theta + \frac{x}{Z})^2} - 1\right]$$

$\cos\theta$ = Load P.F. assume .8

$\sin\theta$ = Reactive P.F. = .6

MRO FORM 1550
1 OCT 72

OMAHA DISTRICT — **COMPUTATION SHEET** — CORPS OF ENGINEERS

PROJECT N.W. Boun. Cont. - R.M.A.	SHEET NO. 7	OF 9
ITEM Primary Line Design	BY KEA	DATE 2/9/85
	CHKD. BY	DATE

r = AC resistance / mile

x = reactance / mile

z = equivalent impedance / mile $\frac{V_N}{\ell I}$

$V_N = 7200$

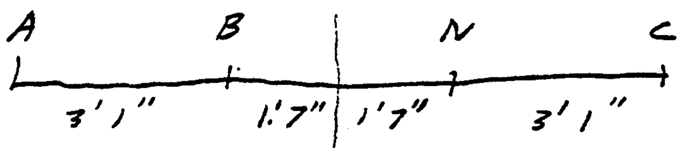
$\ell = 2900' / 5280'/\text{mile} = .55$ miles

$I = 27$ Amps

$$\therefore \quad z = \frac{7200 \text{ Volts}}{(27 \text{ Amps})(.55 \text{ miles})} = 485 \frac{\Omega}{\text{mile}}$$

OH Equivalent conductor spacing - assume 3ϕ & N on 1 cross arm

8' cross arm needed by NESC table



$\overline{AB} = 37''$

$\overline{BC} = 75''$

$\overline{CA} = 112''$

$$D = \sqrt[3]{\overline{AB} \cdot \overline{BC} \cdot \overline{CA}}$$

$$= \sqrt[3]{310800} = 67.74''$$

$$= 5.64'$$

use 6' eq. spacing

MRO FORM 1550
1 OCT 72

Page ______

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT N.W. Boun. Cont. - R.M.A.	SHEET NO. 8 OF 9	
ITEM Primary Line Design	BY KEA	DATE [illegible]
	CHKD. BY	DATE

Design towards maintaining 2% Voltage Drop at the end of the line. Calc. will be based on design load + 50% growth.

Pole Line distance is 2900'

Conductor values from Reynolds Aluminum Electric

Conductor Data (A- 6' spacing)

X #4 = .839
#6 = .869

r calcs.

Determine Amps/in^2 (Amps = 27)

#4 area = .0383 $\frac{27}{.0383}$ = 705 Amps/in^2

#6 area = .0240 $\frac{27}{.0240}$ = 1125 Amps/in^2

#4 use 600 A/in^2 chart

#6 use 1200 A/in^2 chart

r for #4 = 2.24

r for #6 = 3.56

OMAHA DISTRICT | COMPUTATION SHEET | CORPS OF ENGINEERS

PROJECT N.W. Boro. Cont. - R.M.A.	SHEET NO. 9	OF 9	
ITEM Primary Line Design	BY KEA	DATE 2/9/83	
	CHKD. BY	DATE	

Try #6

$\cos\theta = .8 \quad \sin\theta = .6 \quad r = 3.56 \quad x = .869 \quad z = 485$

$$\% \text{ drop} = 100\left[\sqrt{\left(\cos\theta + \frac{r}{z}\right)^2 + \left(\sin\theta + \frac{x}{z}\right)^2} - 1\right]$$

$$= 100\left[\sqrt{\left(.8 + \frac{3.56}{485}\right)^2 + \left(.6 + \frac{.869}{485}\right)^2} - 1\right]$$

$$= 100\left[\sqrt{(.6512) + (.3621)} - 1\right]$$

$$= 100\left[1.0069 - 1\right]$$

$$= 100(.0069)$$

$$= .69$$

#6 is adequate so use

#6 ACSR

Use Tables in A E Manual

To determine pole class

and cross arm sizes

MRO FORM 1 OCT 72 1550

CHAPTER IV - GRADING, DRAINAGE, PAVEMENT, AND FENCE

1. **GENERAL**. Design was based on the following criteria.

1.1 TM 5-820-1, "Surface Drainage Facilities for Airfields," dated August 1965.

1.2 TM 5-820-2, "Subsurface Drainage Facilities for Airfields," dated March 1979.

1.3 TM 5-580-3, "Drainage and Erosion-Control Structures for Airfields and Heliports," January 1978.

1.4 TM 5-820-4, "Drainage for Areas Other than Airfields," dated July 1965.

1.5 TM 5-822-2, "General Provisions and Geometric Design for Roads, Streets, Walks, and Open Storage Areas," dated April 1977.

1.6 TM 5-822-5, "Flexible Pavements for Roads, Streets, Walks, and Open Storage Areas," dated May 1980.

1.7 TM 5-822-6, "Rigid Pavement for Roads, Streets, Walks, and Open Storage Areas."

1.8 EM 1110-2-2902, "Conduits, Culverts, and Pipes."

1.9 "Handbook of Steel Drainage and Highway Construction Products," dated 1971, pages 214-21, on Corrosion.

1.10 EIRS Bulletin 77-06 "Pavement Design."

1.11 Letter Department of the Army OCE "Flexible Pavement Design Curves for Roads and Streets."

1.12 TM 5-818-2 "Pavement Design for Frost Conditions," dated July 1965.

2. **GRADING, BASIS OF DESIGN.**

2.1 Desirable minimum slope of 2 percent on pavement.

2.2 Minimum slope of 5 percent for 10 feet from building, except on pavement which is less.

2.3 Desirable slope of 10 percent for 10 feet from building.

2.4 Desirable overlot grade of 3 percent.

3. **DRAINAGE.**

3.1 Reference: Department of the Army Manuals TM 5-820-1, 2, 3, and 4.

3.2 **GENERAL.** The rainfall at Rocky Mountain Arsenal design has been based on a 1.8 inch, 1-hour rainfall for a ten (10) year frequency. Runoff from the pavement and graded areas will be picked up by the new storm drainage system, draining into the existing system.

3.2.1 Drainage system design will be based on use of fully paved bituminous coated CMP, RCP, or bituminous coated CMP. All pipes in this project are culverts with a minimum size of 24 inches.

3.2.2 Runoff was evaluated on using the COE Modified Rational Method where the runoff coefficients for paved area was 1 and for turf areas was 0.5.

4. **PAVING.**

4.1 All paving with portland cement as proposed in the Concept Design Analysis was deleted from the project or requested by the Project Engineer in order to reduce cost.

4.2 A crushed rock roadway 6-inch thick shall be used as a substitute for all pavement in the project, except for the entrance to Highway 6 and 2, which is State of Colorado property. They require a 9-inch thick Bituminous Intersection; which we shall provide as shown on the drawings.

5. **FENCE.** A chain link fence gate was provided in the fence line at the new road connection to the highway.

CHAPTER V - STRUCTURAL

1. <u>GENERAL PARAMETERS</u>. The in-house structural design includes 15 discharge well concrete valve pit vaults, 21 recharge well concrete valve pit vaults, 1 sump concrete vault, and 15 well cap/water level recorder support assemblies. All of the above are entirely original designs. All other structural design has been performed by the Architect-Engineer firm handling the treatment portion of this project.

All 15 discharge wells and all 21 recharge wells are to use the same concrete valve pit vault design. Inside dimensions of the valve pit vault are 8'-0" long x 5'-6" wide x 7'-0" high. All walls, roof, and floor slabs are to be 6-inch thick reinforced concrete slabs. The top of the vault roof slab is to be 1'-6" above finish grade to prevent vehicular loadings to the structure. The roof slab is provided with a 3'-6" x 3'-6" manhole frame and lid for access. The floor slab is sloped toward an 8-inch diameter floor drain.

The sump vault is actually a two-compartment structure with a base floor slab, intermediate floor slab, and roof slab for each compartment. The two compartments have a common vertical wall which serves as a watertight barrier between them. Furthermore, the vault exterior walls must also be watertight below the intermediate slab level. Each compartment contains four pumps supported by the intermediate slab. The lower portion of each compartment, below the intermediate slab level, is designed to withstand exterior soil pressures as well as interior hydrostatic pressures. The walls have been designed for the lower compartment areas to be full, dry, or filled with water to any intermediate level, with the additional consideration that the water levels in the two compartments are independent of each other.

The inside dimensions of the lower compartments are 20'-0" long x 10'-0" wide x 12'-6" high while the upper compartments are 20'-0" long x 10'-0" wide x 7'-0" high. The vault is symmetrical about the 20'-0" long common wall between the two structurally mirror-image compartments. The vault base slab and all vault walls, interior and exterior, are 12-inch thick reinforced concrete slabs. The vault roof and intermediate slabs are 10-inch thick reinforced concrete slabs.

The roof, intermediate, and base slabs are each designed, basically, to act with two-span continuous beam action with the common compartment wall as the intermediate support. The intermediate slab is provided with openings for four pumps and one grated access hatch in each compartment. The roof slab is provided with four manhole frames and lids for each compartment, with each opening being centered over one of the pumps on the intermediate slab below. Due to the size and number of openings in the roof and intermediate slabs, as well as their symmetrics about the common compartment wall, heavily reinforced beam strips are actually used to carry the slab loads across the two-span condition over the two vault compartments.

The vault is to be constructed with the top of the roof slab 6'-2" above finish grade and the bottom of base slab 16'-0" below finish grade. Ground water is first encountered at a minimum of 20 feet below grade. Therefore, buoyancy effects and exterior hydrostatic pressures are not factors in the vault design. One personnel door is provided in the long exterior wall of each compartment.

Finally, a water level recorder is required at each of the 15 recharge wells. This instrument is very sensitive to movement and therefore requires a very stable support structure. The recorder must be placed immediately above the well casing which must be sealed off from the environment above. A float and counterweight are suspended from a pulley on the recorder and must penetrate the sealed well cap. The requirements for a well cap and recorder support assembly which are easily removeable (for access to the well) resulted in a design for the cap and support assembly which can be mounted to, or removed from, the well casing by as few as 6 bolts. The cap is 3/8-inch steel plate and the recorder support is a 2" x 2" x 1/4" angle frame with a 3/4" x 18" x 18" plywood deck.

2. APPLICABLE CRITERIA.

2.1 PUBLICATIONS.

2.1.1 Project Design Directive.

2.1.2 Project Book.

2.1.3 Architect-Engineer Instruction Manual - Omaha District Corps of Engineers.

2.1.4 Building Code Requirements for Reinforced Concrete (ACI 318-77).

2.1.5 TM 5-809-1 Load Assumption for Buildings.

2.1.6 TM 5-809-2 Concrete and Structural Design for Buildings.

2.1.7 Metal Bar Grating Manual (National Association of Architectural Metal Manufacturers).

2.2 DESIGN DATA.

2.2.1 Climatic and Geographical Conditions.

Design Footing Dept, minimum	3'-6"
Allowable Excess Soil Bearing Pressure	1200 psf
Seismic Zone	1
Basic Wind Speed (50 year)	80 mph
Ground Snow Load	35 psf
In-Place Soil Density	135 pcf
Ground Water Level	20+ feet below grade

2.2.2 Materials

Concrete (All Work)	f'c = 4000 psi
Reinforcing Steel	fy = 60,000 psi

2.2.3 Design Loads

All Vault Roof Uniform Live Loads	100 psf
Sump Vault Intermediate Slab Uniform Live Load	100 psf
Assumed Sump Vault Pump Weight (eight locations)	1600 lb.
Wind Loads	Not critical
Seismic Loads	Not critical
Lateral Earth Pressures on Vault Walls, At-Rest Pressure Coefficient	$K_o = 0.5$

3. **CALCULATIONS** - See Appendix D

PART III

OPERATIONS AND MAINTENANCE PROVISIONS

PART III - OPERATIONS AND MAINTENANCE PROVISIONS

1. INTENDED USER RESPONSIBILITIES FOR O&M.

1.1 CONTROL RESPONSIBILITIES.

1.1.1 Monitoring and reporting to the concerned agencies flow, contaminant concentration, and water levels at the discharge, recharge, and monitoring wells.

1.1.2 Programs for prevention and control of spills and pollution of ground and surface waters.

1.1.3 Ultimate disposal of the organic contamination and spent activated carbon in accordance with the applicable regulations.

1.1.4 Coordination of the overall pollution control and monitoring for the installation.

1.2 SERVICE RESPONSIBILITIES.

1.2.1 Equipment maintenance in accordance with the manufacturer's recommendations.

1.2.2 Replacement of filter cartridges and spent activated carbon.

1.2.3 Adjustment of flow control valves at the individual wells to compensate for seasonal changes in ground water flux.

1.2.4 Overall building and grounds maintenance consistent with public health, sanitation, and weed control requirements.

2. DESIGN PROVISIONS FOR O&M ENHANCEMENT AND COST REDUCTION.

2.1 CONTROL RELATED.

2.1.1 A site inspection on 31 March and 9 April 1982 revealed problem areas on the previous ground water contamination projects on Rocky Mountain Arsenal. An attempt to solve the problems has been made. The most obvious revisions were in the valve pit design. Manual operation and mechanical in lieu of electronic control systems should eliminate some of the failures.

2.1.2 The hydraulic barrier method of containment gives the user the flexibility of gradual reduction of the dewatering system as the contamination plume tapers off.

2.2 SERVICE RELATED

2.2.1 Four pump systems for the treatment plant influent and effluent flows will allow treatment plant operation and recharge at rates similar to the ground water flux rates.

2.2.2 Spare pumps and motors for the discharge wells were furnished to maintain the dewatering system. Two pumps were specified. One adequate for the largest capacity wells and the other for the lower capacity wells.

APPENDIX A

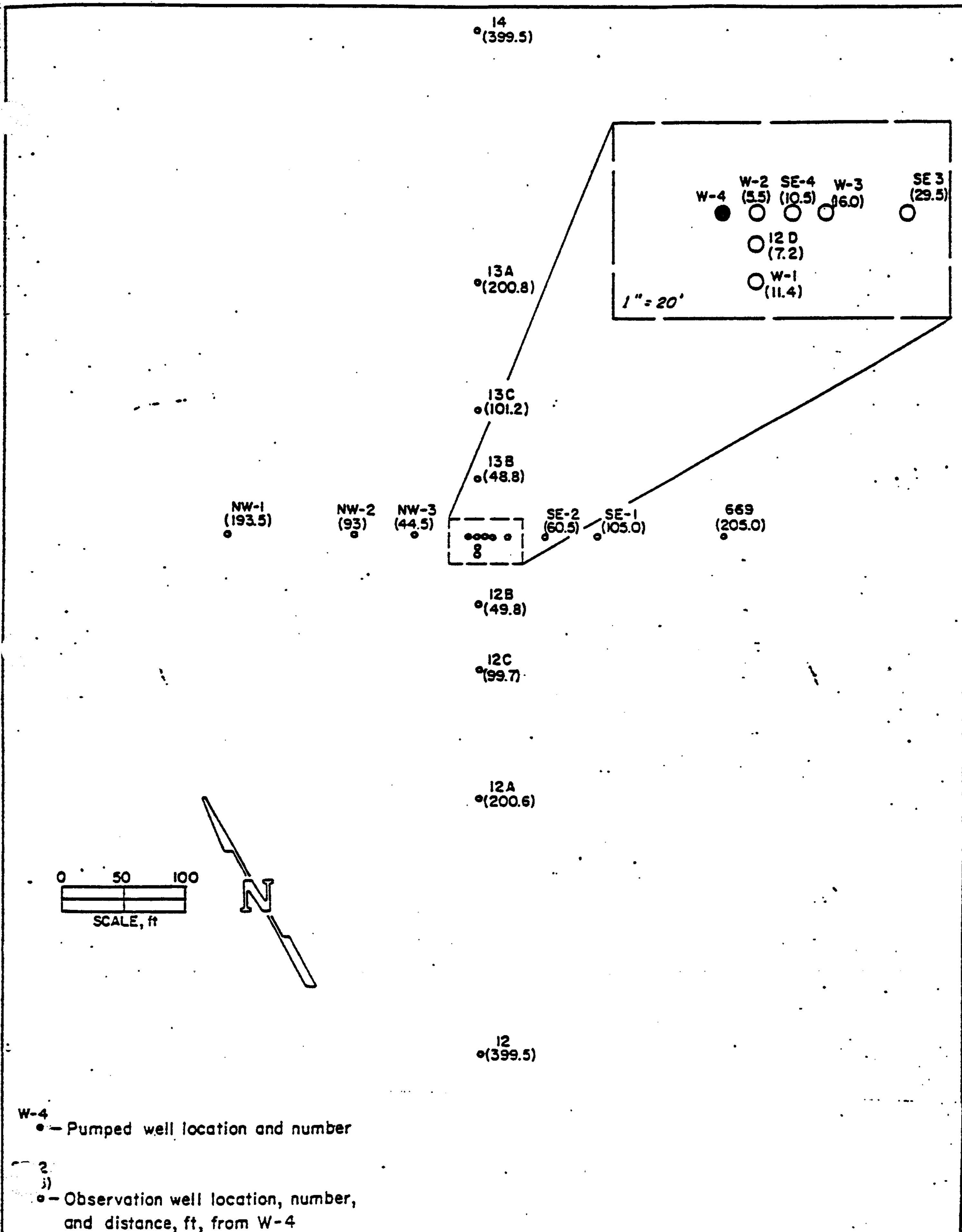
GEOTECHNICAL ANALYSIS

<u>INDEX TO GEOTECHNICAL ANALYSES</u>

1. AQUIFER PUMP TEST DATA - WELL NO. W-4
2. AQUIFER PUMP TEST DATA - WELL NO. W-5
3. SLUG TEST IN W-5A
4. GRAVEL FILTER PACK DESIGN
5. SOIL CLASSIFICATION RECORD SHEETS
6. DRAWDOWN ANALYSIS USING MUSKAT EQUATION
7. CUTOFF WALL HYDRAULIC ANALYSIS
8. COMPUTER MODEL

AQUIFER PUMP TEST DATA

WELL NO. W-4



OBSERVATION WELL LOCATION PLAN

FIG. NO. 1

BY CGB DATE 6/29/82 PROJECT NAME RMA PROJECT NUMBER M82-41

CHKD. BY ______ DATE ______ SUBJECT WELL DRAWDOWN DATA SHEET NO. 1 OF 10

12-D				SE-4			
ELAPSED TIME (Δt)	DRAWDOWN (D)	Δt	D	Δt (min)	D (ft)	Δt (min)	D (ft)
0 min.	0.00 ft.	1869 min.	2.15 ft	0	0.00	2605	1.96
.38	0.96	1917	2.17	.38	0.55	2693	1.96
.78	0.99	2006	2.17	.78	0.63	2789	1.98
1.53	1.03	2085	2.21	1.53	0.67		
3.0	1.07	2160	2.23	3	0.69		
3.75	1.08	2250	2.24	3.75	0.72		
10.	1.16	2334	2.27	9.25	0.81		
14.75	1.21	2434	2.28	14.5	0.87		
17.5	1.23	2518	2.31	18	0.89		
20	1.25	2612	2.32	27	0.95		
27	1.29	2700	2.33	37.25	0.96		
35.75	1.33	2791	2.47	45	0.99		
44.25	1.36			53	1.01		
51	1.39			57	1.05		
57	1.41			75	1.09		
75	1.47			198	1.24		
114	1.48			255	1.31		
130	1.51			348	1.36		
140	1.52			456	1.43		
170	1.55			546	1.48		
198	1.57			626	1.51		
255	1.63			729	1.55		
348	1.68			805	1.52		
456	1.75			897	1.54		
546	1.79			985	1.55		
626	1.83			1071	1.61		
714	1.85			1257	1.65		
803	1.88			1346	1.56		
895	1.98			1454	1.71		
896	1.92			1530	1.72		
986	1.95			1623	1.75		
1074	1.99			1715	1.79		
1162	2.00			1804	1.79		
1260	208			1914	1.82		
1262	2.03			2002	1.82		
1349	2.11			2077	1.86		
1353	2.05			2158	1.86		
1463	2.15			2249	1.88		
1473	2.08			2328	1.90		
1628	2.11			2425	1.92		
1716	2.13			2513	1.94		

BY SEF DATE 6-29-82 PROJECT NAME RMA PROJECT NUMBER M82-41

CHKD. BY ______ DATE ______ SUBJECT WELL DRAWDOWN DATA SHEET NO. 2 OF 10

NW-1				SE-3			
Δt(min)	D(ft)	Δt(min)	D(ft)	Δt(min)	D(ft)	Δt(min)	D(ft)
0	0.00	1911	0.73	0	0.00	893	1.19
7.0	0.23	1990	0.75	0.5	0.33	990	1.23
9.0	0.04	2074	0.79	1.0	0.38	1065	1.25
11.1	0.04	2153	0.79	1.5	0.38	1154	1.23
13.1	0.04	2233	0.79	2.0	0.40	1164	1.25
15.1	-0.02	2323	0.81	2.5	0.42	1248	1.27
17.1	0.00	2420	0.79	3.0	0.44	1334	1.33
19.1	0.04	2504	0.81	3.5	0.44	1412	1.38
26	0.02	2597	0.81	4.0	0.46	1701	1.40
30.3	0.04	2683	0.83	4.5	0.46	1507	1.42
35.1	0.04	2774	0.83	5	0.48	1905	1.47
40.3	0.04			7	0.48	2000	1.46
45.5	0.06			9	0.54	2081	1.48
50.3	0.06			11	0.52	2163	1.50
55.3	0.06			13	0.54	2247	1.52
60.3	0.08			15	0.56	2329	1.53
70.2	0.08			17	0.58	2429	1.54
80.4	-0.08			19	0.60	2516	1.57
90.4	0.00			22	0.60	2609	1.58
110	0.00			25	0.63	2697	1.58
130	0.40			30	0.63	2787	1.60
151	0.19			35	0.69		
174	0.25			40	0.71		
252	0.33			45	0.71		
336	0.38			50	0.73		
477	0.42			55	0.75		
550	0.42			60	0.77		
631	0.46			70	0.79		
724	0.48			80	0.79		
812	0.50			89	0.81		
909	0.52			110	0.83		
1004	0.54			130	0.88		
1076	0.56			150	0.90		
1172	0.60			170	0.92		
1256	0.63			269	0.98		
1345	0.63			350	1.02		
1446	0.65			464	1.08		
1532	0.67			543	1.16		
1621	0.67			637	1.10		
1707	0.69			712	1.15		
1799	0.71			817	1.17		

BY G.C.S. DATE 6-29-82 PROJECT NAME RMA PROJECT NUMBER M82-41

CHKD. BY ______ DATE ______ SUBJECT WELL DRAWDOWN DATA SHEET NO. 4 OF 10

13-B				NW-3			
Δt(min)	D(ft)	Δt(min)	D(ft)	Δt(min)	D(ft)	Δt(min)	D(ft)
0	0.00	991	1.23	0	0.00	905	0.85
0.5	0.08	1079	1.23	0.5	0.21	1002	0.90
1	0.25	1175	1.25	1	0.29	1073	0.92
1.5	0.21	1263	1.27	1.5	0.29	1167	0.94
2	0.27	1347	1.31	2	0.33	1254	0.96
2.5	0.27	1436	1.35	2.5	0.44	1343	0.98
3	0.29	1525	1.35	3	0.44	1442	1.00
3.5	0.29	1612	1.35	3.5	0.44	1530	1.00
4	0.31	1704	1.40	4	0.44	1618	1.02
4.5	0.31	1794	1.40	4.5	0.44	1704	1.06
5	0.31	1917	1.46	5	0.44	1798	1.08
7	0.35	1994	1.44	7	0.46	1906	1.13
9	0.38	2077	1.46	9	0.46	1985	1.13
11	0.38	2157	1.48	11	0.50	2070	1.15
13	0.40	2237	1.48	13	0.52	2150	1.17
15	0.42	2327	1.50	15	0.52	2230	1.17
17	0.44	2430	1.52	17	0.54	2321	1.21
19	0.46	2515	1.54	19	0.54	2436	1.17
24	0.50	2606	1.54	21	0.54	2519	1.19
29	0.52	2700	1.56	26.2	0.54	2609	1.21
34	0.52	2786	1.56	31.2	0.56	2694	1.21
39	0.54			36.2	0.56	2782	1.25
44	0.58			41.2	0.67		
49	0.60			46.2	0.67		
54	0.60			51.2	0.71		
60	0.65			55	0.71		
70	0.65			60	0.75		
80	0.69			70	0.73		
90	0.69			80	0.75		
110	0.71			90	0.75		
134.5	0.75			110	0.79		
150	0.77			142	0.90		
170	0.79			160	0.92		
268	0.88			184	0.92		
350	0.92			195	1.08		
473	1.04			349	1.08		
546	1.06			469	1.10		
634	1.10			542	0.75		
719	1.13			627	0.77		
811	1.16			720	0.81		
915	1.20			805	0.83		

BY GS DATE 6-29-82 PROJECT NAME RMA PROJECT NUMBER MEZ-41

CHKD. BY ____ DATE ____ SUBJECT WELL DRAWDOWN DATA SHEET NO 5 OF 10

W-2 (P-2)

Δt(min)	D(ft)	Δt(min)	D(ft)
0	0.00	1062	1.91
0.5	0.10	1153	1.93
1	0.15	1242	1.96
1.5	0.20	1335	1.96
2	0.26	1437	1.93
2.5	0.32	1521	1.98
3	0.32	1615	2.03
3.5	0.36	1701	2.02
4	0.43	1793	2.13
4.5	0.43	1901	2.08
5	0.45	1981	2.08
7	0.58	2067	2.11
9	0.67	2149	2.13
11	0.79	2232	2.14
13	0.85	2319	2.18
15	0.93	2413	2.13
17	0.96	2503	2.16
19	1.05	2593	2.18
20		2683	2.18
25	1.07	2771	2.21
30	1.12		
35	1.17		
40	1.19		
45	1.20		
50	1.26		
55	1.25		
60	1.23		
65	1.24		
87	1.23		
105	1.24		
139	1.19		
170	1.33		
255	1.38		
345	1.44		
455	1.63		
532	1.66		
643	1.53		
718	1.75		
794	1.78		
893	1.89		
976	1.91		

SE-2

Δt(min)	D(ft)	Δt(min)	D(ft)
0	0.00	1067	1.06
0.75	0.15	1158	1.13
1.75	0.17	1245	1.13
2.25	0.23	1337	1.17
3	0.23	1426	1.19
3.75	0.25	1519	1.19
4.5	0.29	1607	1.21
5	0.29	1696	1.25
5.8	0.31	1787	1.27
8	0.31	1921	1.29
9.5	0.46	2009	1.29
11	0.48	2087	1.29
13	0.46	2159	1.31
15	0.50	2248	1.35
17	0.50	2335	1.35
19	0.46	2441	1.40
21	0.44	2524	1.40
25	0.50	2610	1.40
30	0.52	2698	1.42
35	0.50	2785	1.44
40	0.50		
45	0.50		
50	0.52		
55	0.54		
60	0.56		
70	0.58		
80	0.60		
90	0.60		
110	0.65		
130	0.67		
150	0.69		
170	0.69		
274	0.77		
361	0.83		
456	0.90		
530	0.93		
618	0.96		
711	0.99		
794	1.02		
893	1.05		
977	1.06		

BY CGS DATE 6-29-82 PROJECT NAME RMA PROJECT NUMBER M82-41

CHKD. BY ______ DATE ______ SUBJECT WELL DRAWDOWN DATA SHEET NO. 6 OF 10

669				13-A			
Δt(min)	D(ft)	Δt(min)	D(ft)	Δt(min)	D(ft)	Δt(min)	D(ft)
0	0.00	1790	0.68	0	0.00	2053	0.83
0.9	-0.01	1929	0.72	4.8	0.00	2162	0.85
4.9	0.01	2015	0.74	9.5	0.02	2241	0.86
7.4	0.01	2091	0.76	13.5	0.02	2332	0.86
10.2	0.02	2157	0.78	18.5	0.04	2422	0.88
13	0.01	2247	0.80	23	0.06	2509	0.89
16	0.02	2339	0.80	27	0.06	2599	0.90
18.5	0.03	2435	0.80	32.5	0.08	2687	0.92
21.5	0.03	2522	0.82	36.5	0.08	2777	0.92
26.5	0.05	2609	0.82	40.5	0.10		
31.5	0.06	2701	0.84	45.5	0.10		
36.5	0.07	2785	0.86	50	0.10		
41.5	0.07			57.5	0.13		
46.5	0.08			62.5	0.13		
51.5	0.08			72	0.13		
56.5	0.09			82	0.15		
61.5	0.09			91	0.17		
71.5	0.11			113	0.19		
81.5	0.11			133	0.21		
91.5	0.15			153	0.21		
111	0.15			172	0.25		
131	0.17			276	0.29		
151	0.18			358	0.35		
171	0.20			466	0.43		
289	0.28			543	0.45		
353	0.30			628	0.48		
458	0.37			720	0.51		
532	0.40			805	0.54		
622	0.43			908	0.58		
715	0.46			996	0.58		
798	0.49			1079	0.60		
901	0.51			1170	0.65		
984	0.53			1257	0.65		
1071	0.55			1349	0.69		
1163	0.57			1438	0.71		
1250	0.57			1529	0.71		
1342	0.64			1616	0.71		
1430	0.64			1707	0.75		
1522	0.66			1797	0.77		
1610	0.66			1922	0.79		
1700	0.68			1999	0.81		

BY CGB DATE 6-29-82 PROJECT NAME RMA PROJECT NUMBER M82-41

CHKD. BY ______ DATE ______ SUBJECT WELL DRAWDOWN DATA SHEET NO. 7 OF 10

12-C

Δt(min)	D(ft)	Δt(min)	D(ft)
0	0.00	897	0.81
0.25	0.00	990	0.83
0.75	0.06	1067	0.85
1.25	0.06	1157	0.88
1.75	0.08	1247	0.90
2.25	0.10	1337	0.92
2.75	0.13	1434	0.94
3.25	0.13	1522	0.96
3.75	0.13	1609	0.98
4.25	0.13	1697	0.98
5.25	0.13	1788	1.00
6.25	0.15	1907	1.04
8.25	0.17	1992	1.04
9.25	0.19	2076	1.05
10.5	0.21	2152	1.08
12.5	0.21	2237	1.13
15	0.23	2323	1.13
16.5	0.23	2417	1.13
18.5	0.25	2511	1.15
25	0.27	2600	1.15
30	0.29	2687	1.17
35	0.29	2775	1.17
40	0.31		
45	0.33		
50	0.33		
55	0.35		
60	0.38		
70	0.38		
80	0.40		
90	0.42		
110	0.44		
130	0.44		
150	0.46		
170	0.48		
316	0.52		
344	0.54		
458	0.63		
533	0.69		
620	0.73		
713	0.75		
797	0.79		

14

Δt(min)	D(ft)	Δt(min)	D(ft)
0	0.00	2087	0.54
1.1	0.00	2165	0.56
7	0.00	2245	0.58
11	0.00	2336	0.58
16.5	0.00	2418	0.58
21	0.00	2506	0.60
25	0.00	2596	0.60
30	0.00	2685	0.63
34.5	0.00	2775	0.63
38.5	0.00		
43	0.00		
47.5	0.02		
52.5	0.02		
60	0.02		
70	0.02		
80	0.02		
90	0.02		
110	0.04		
130	0.04		
150	0.06		
170	0.08		
281	0.13		
355	0.13		
464	0.19		
538	0.21		
628	0.24		
718	0.26		
803	0.28		
906	0.31		
1000	0.33		
1078	0.35		
1170	0.38		
1255	0.38		
1348	0.40		
1442	0.42		
1532	0.44		
1620	0.46		
1710	0.46		
1800	0.48		
1926	0.52		
2003	0.52		

BY [initials] DATE 6-29-82 PROJECT NAME RMA PROJECT NUMBER M82-41

CHKD. BY ______ DATE ______ SUBJECT WELL DRAWDOWN DATA SHEET NO 8 OF 10

NW-2				SE-1			
Δt(min)	D(ft)	Δt(min)	D(ft)	Δt(min)	D(ft)	Δt(min)	D(ft)
0	0.00	1620	1.10	0	0.00	1688	1.00
1	0.20	1705	1.13	1	0.04	1788	1.02
2	0.20	1797	1.15	3	0.08	1926	1.08
3.5	0.22	1909	1.21	6	0.12	2014	1.08
5	0.21	1987	1.21	9	0.13	2090	1.08
7	0.21	2072	1.23	11.5	0.16	2161	1.10
9	0.23	2151	1.23	14.5	0.17	2250	1.13
11	0.27	2232	1.25	17	0.18	2337	1.13
13	0.27	2322	1.27	20	0.19	2442	1.13
15	0.29	2429	1.25	23	0.21	2522	1.15
20.3	0.33	2513	1.25	28	0.23	2613	1.17
25.8	0.33	2603	1.27	33	0.25	2697	1.17
30	0.33	2689	1.29	38	0.26	2790	1.19
35	0.33	2778	1.29	43	0.28		
40	0.42			48	0.29		
45	0.42			53	0.30		
50	0.42			58	0.31		
55	0.44			63	0.31		
60	0.46			73	0.37		
70	0.48			83	0.37		
80	0.50			93	0.38		
90	0.50			113	0.41		
110	0.54			133	0.44		
130	0.56			153	0.46		
171	0.58			173	0.47		
186	0.69			277	0.54		
258	0.67			357	0.60		
343	0.73			440	0.68		
475	0.79			534	0.70		
547	0.83			619	0.73		
630	0.88			712	0.77		
723	0.90			795	0.78		
810	0.92			896	0.83		
908	0.94			980	0.85		
1004	0.98			1069	0.85		
1075	0.98			1160	0.86		
1169	0.96			1248	0.88		
1255	1.04			1340	0.94		
1345	1.06			1428	0.95		
1449	1.08			1520	0.96		
1531	1.10			1609	1.00		

BY CB3 DATE 6-29-82 PROJECT NAME RMA PROJECT NUMBER M82-41

CHKD. BY ______ DATE ______ SUBJECT WELL DRAWDOWN DATA SHEET NO. 9 OF 10

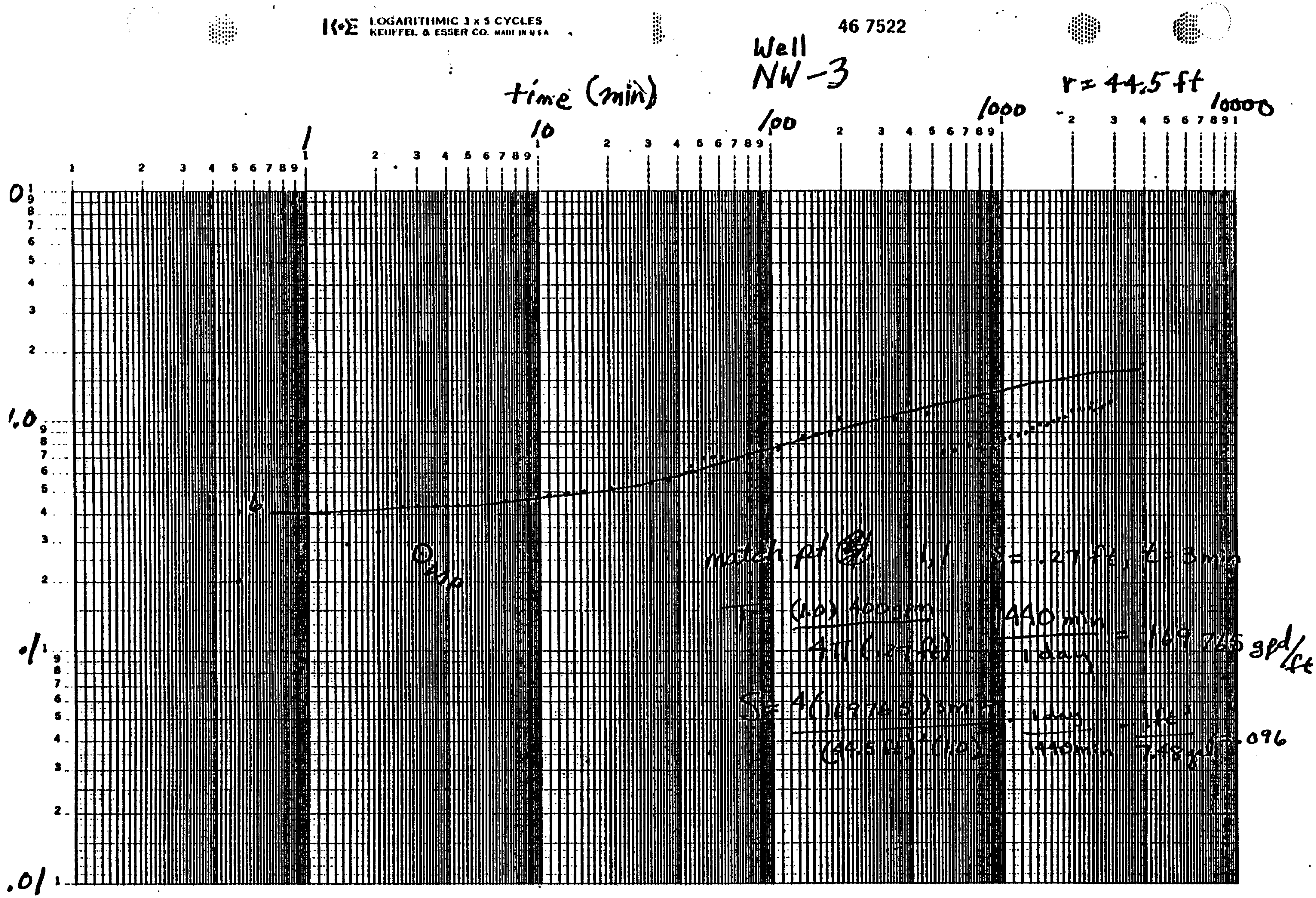
12-A				12-B			
Δt(min)	D(ft)	Δt(min)	D(ft)	Δt(min)	D(ft)	Δt(min)	D(ft)
0	0.00	2153	0.88	0	0.00	1607	1.25
0.5	0.08	2240	0.90	0.6	0.19	1695	1.27
4.5	0.08	2326	0.92	3.7	0.27	1787	1.29
10.5	0.15	2420	0.92	4.8	0.29	1935	1.33
16.5	0.15	2514	0.92	7.0	0.31	1987	1.33
22.5	0.15	2602	0.94	10.0	0.38	2072	1.35
28.5	0.19	2689	0.94	11.5	0.38	2151	1.35
33.5	0.19	2782	0.96	14	0.40	2234	1.38
38.5	0.23	2875	0.96	16.5	0.40	2330	1.40
43	0.23			19	0.42	2422	1.40
48	0.25			24	0.46	2516	1.44
53	0.25			27.5	0.48	2606	1.44
58	0.25			30	0.48	2694	1.44
68	0.27			35	0.50	2752	1.46
78	0.27			40	0.52	2852	1.48
88	0.29			45	0.50		
108	0.29			50	0.54		
128	0.33			55	0.56		
148	0.35			60	0.58		
168	0.38			70	0.60		
255	0.38			80	0.63		
341	0.42			90	0.63		
460	0.50			110	0.67		
536	0.52			130	0.67		
622	0.54			150	0.71		
715	0.58			170	0.73		
798	0.60			266	0.81		
899	0.65			347	0.85		
995	0.67			455	0.92		
1069	0.67			530	0.94		
1161	0.69			617	0.98		
1249	0.73			711	1.00		
1340	0.75			794	1.04		
1437	0.77			895	1.06		
1524	0.77			987	1.10		
1611	0.79			1065	1.15		
1698	0.81			1158	1.15		
1791	0.81			1245	1.19		
1912	0.85			1334	1.19		
1998	0.85			1431	1.21		
2080	0.88			1520	1.23		

BY CCB DATE 6-29-83 PROJECT NAME RMA PROJECT NUMBER MEZ-41

CHKD. BY ______ DATE ______ SUBJECT WELL DRAWDOWN DATA SHEET NO. 10 OF 10

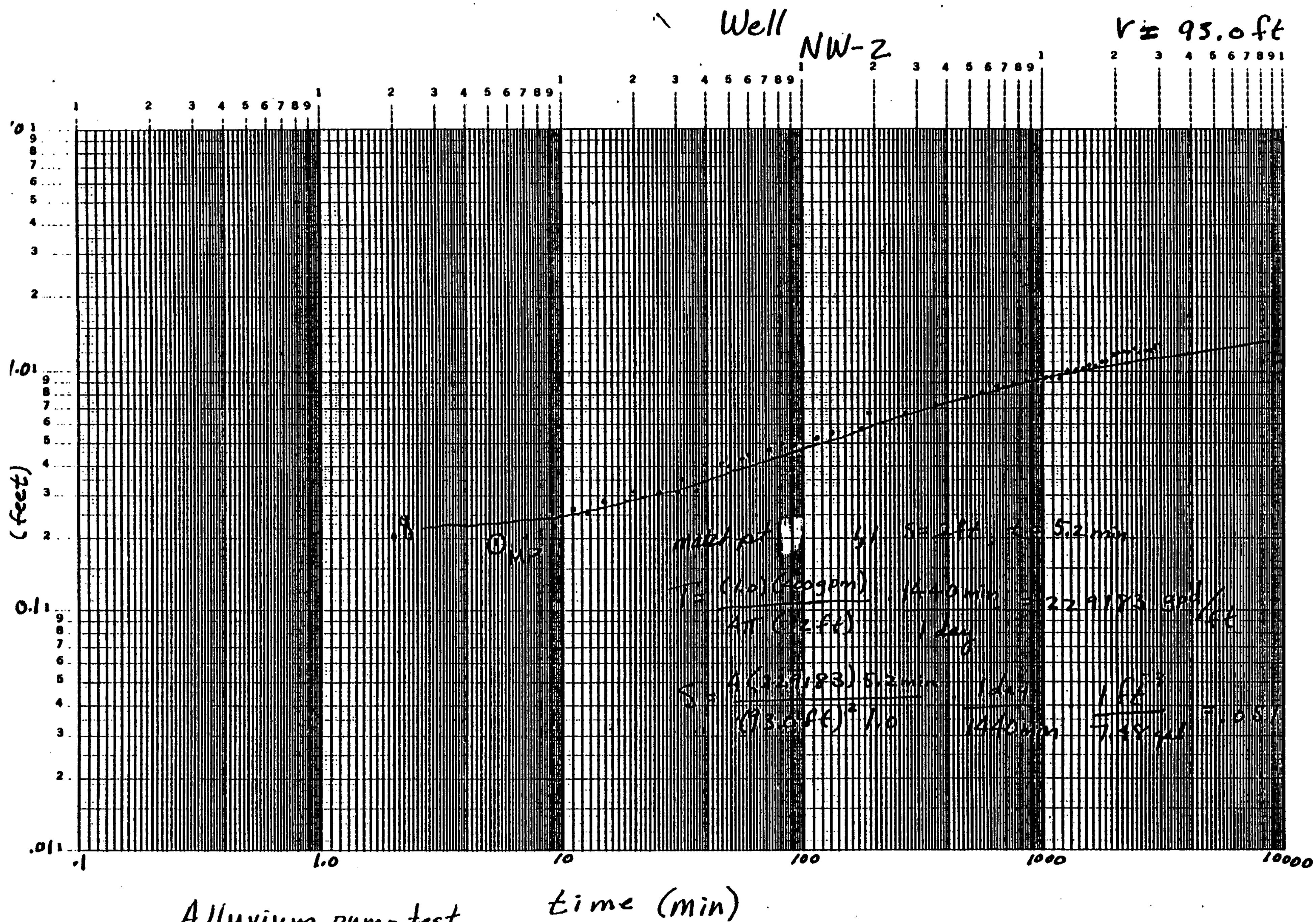
MAIN PUMPING WELL (P-2)

Δt(min)	D(ft)	Δt(min)	D(ft)
0	0.00	1150	11.84
0.5	12.63	1239	11.83
1	11.83	1331	11.58
1.5	12.17	1429	11.63
2	12.37	1524	11.56
2.5	12.52	1612	11.65
3	12.23	1697	11.51
3.5	12.31	1794	11.56
4	12.40	1902	11.74
4.5	12.36	1978	11.83
5	12.48	2064	11.75
7	12.46	2142	11.68
9	12.56	2223	11.78
11	12.62	2316	11.73
13	12.58	2408	11.80
15	12.57	2500	11.80
17	12.52	2591	11.80
19	12.58	2671	11.76
25	12.69	2768	11.80
30	12.57		
35	12.51		
40	12.36		
45	12.51		
50	12.57		
55	12.53		
64	12.53		
74	11.71		
85	11.65		
104	11.73		
137	11.88		
166	11.78		
252	11.93		
336	11.88		
453	11.93		
526	11.92		
631	11.93		
713	12.01		
789	11.93		
887	12.06		
972	11.94		
1057	11.96		



Alluvium pump test

5/26-28 1982



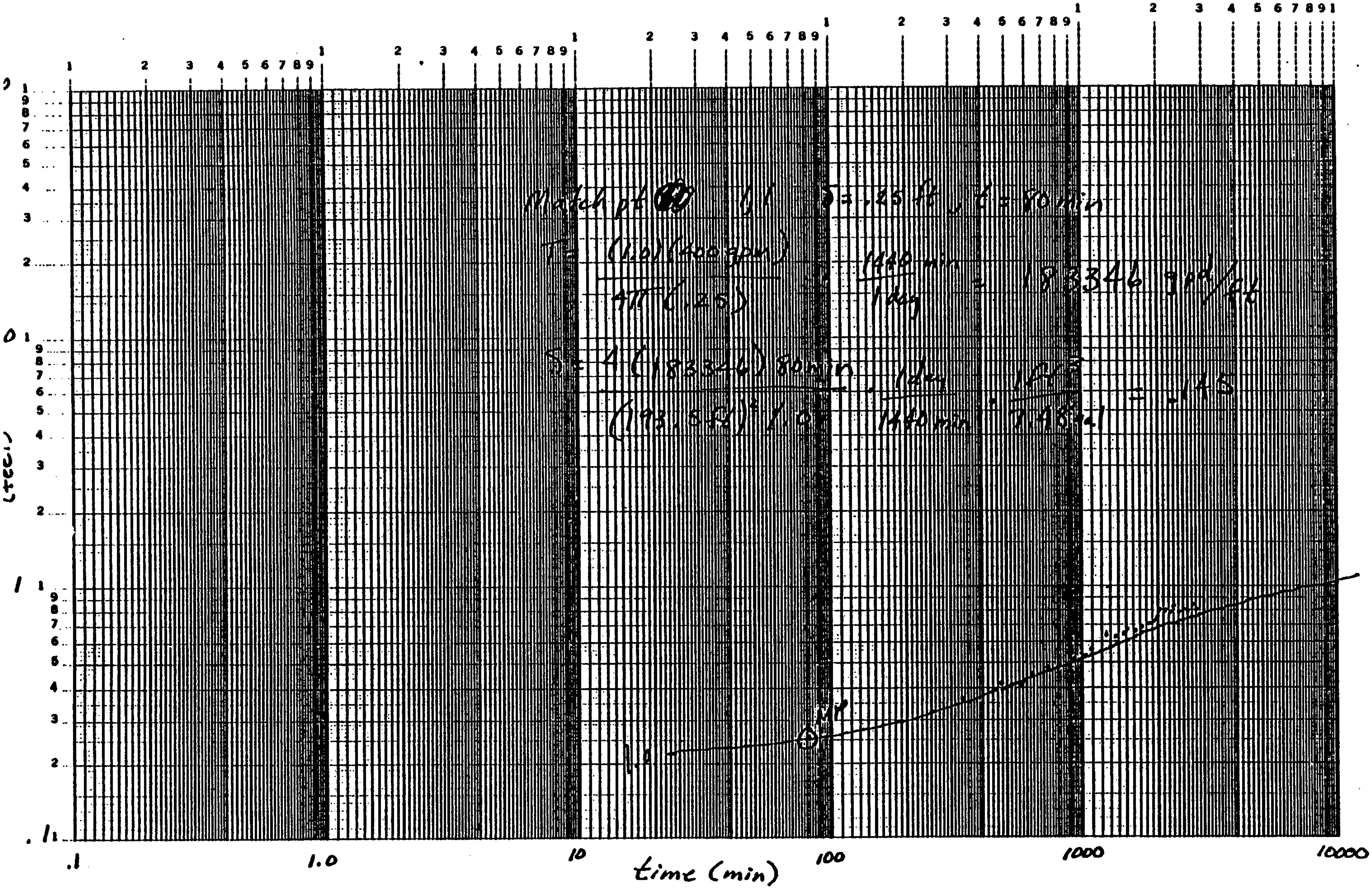
Alluvium pump test

K•E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

Well NW-1

r = 193.5 ft

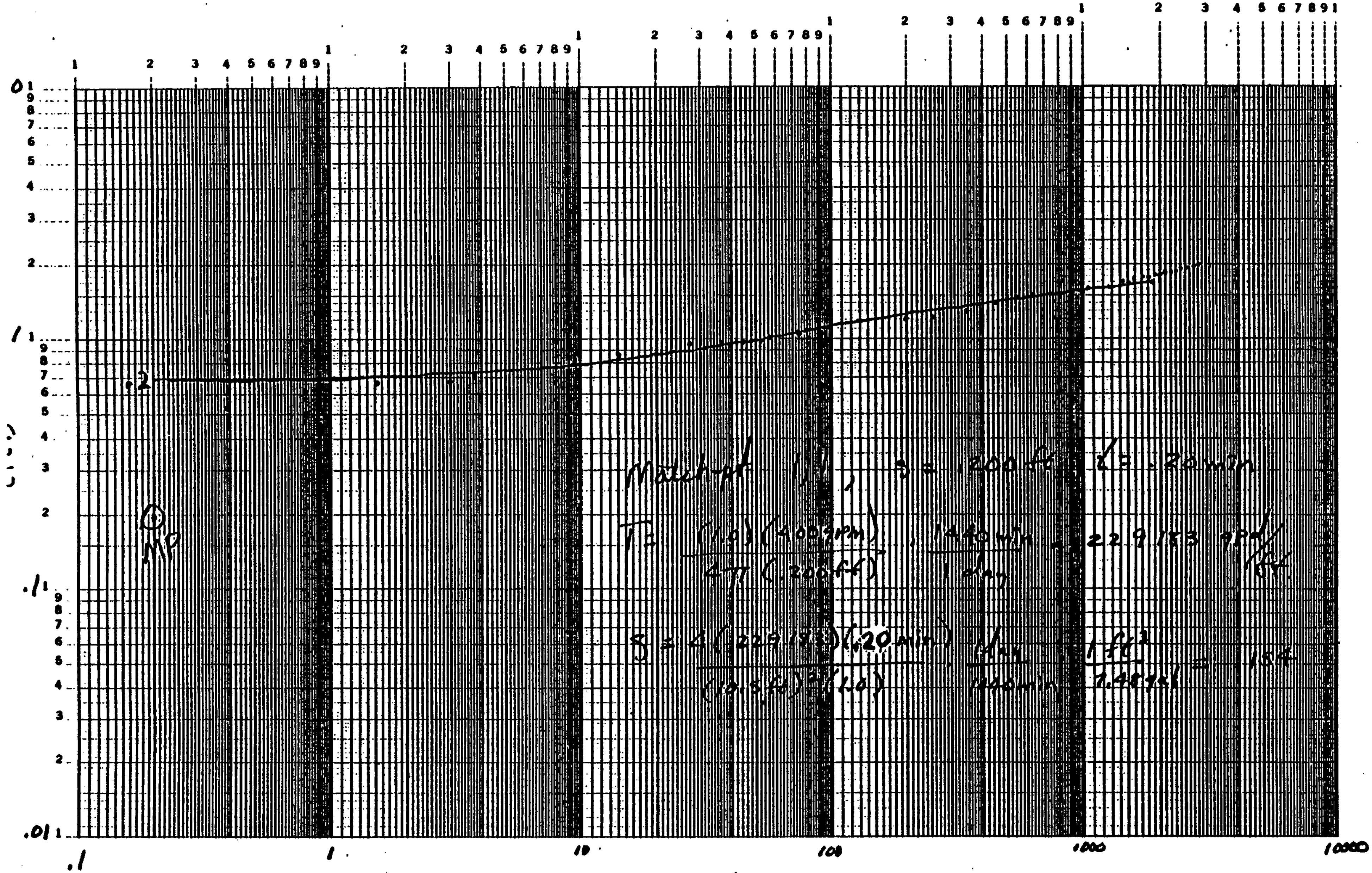


Alluvium pump test

K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

Well SE-4 - r = 10.5 ft.



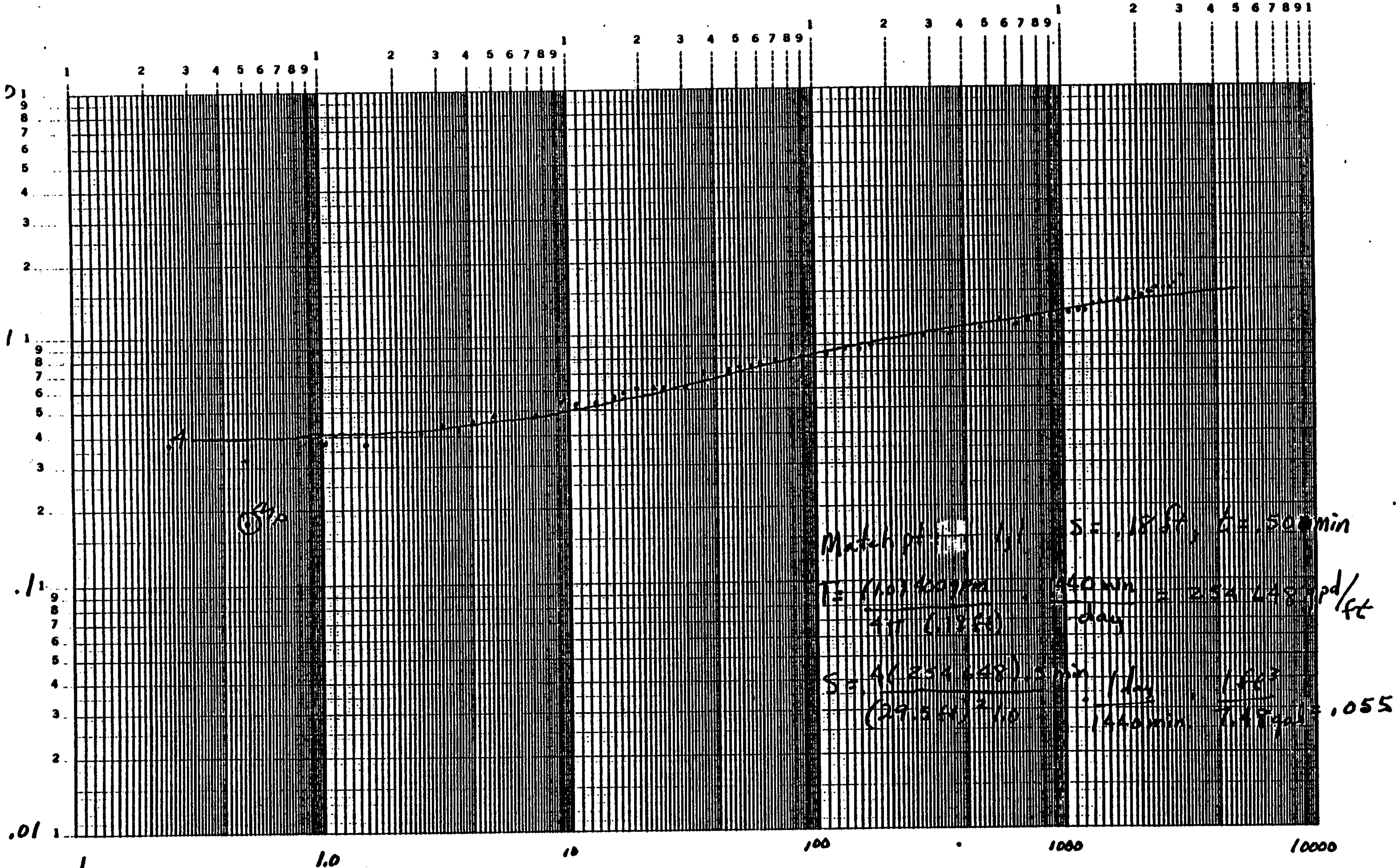
Alluvium Pump Test time (min)

5/... 20/82

K•E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

Well
SE-3 $r = 29.5$ ft.



time (min)

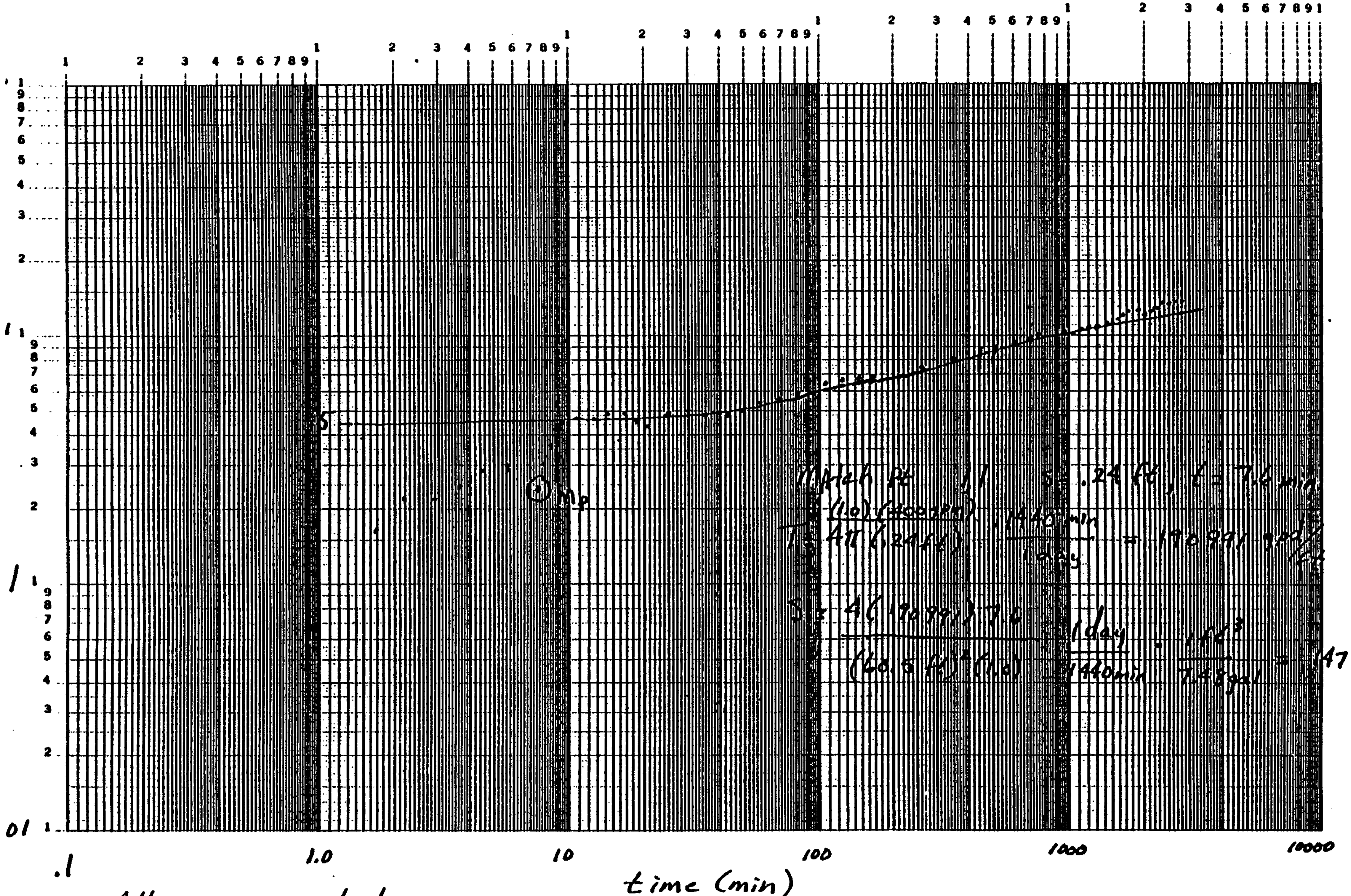
Alluvium pump test
5/21–25/82

LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

Well SE-2

R = 60.5 ft



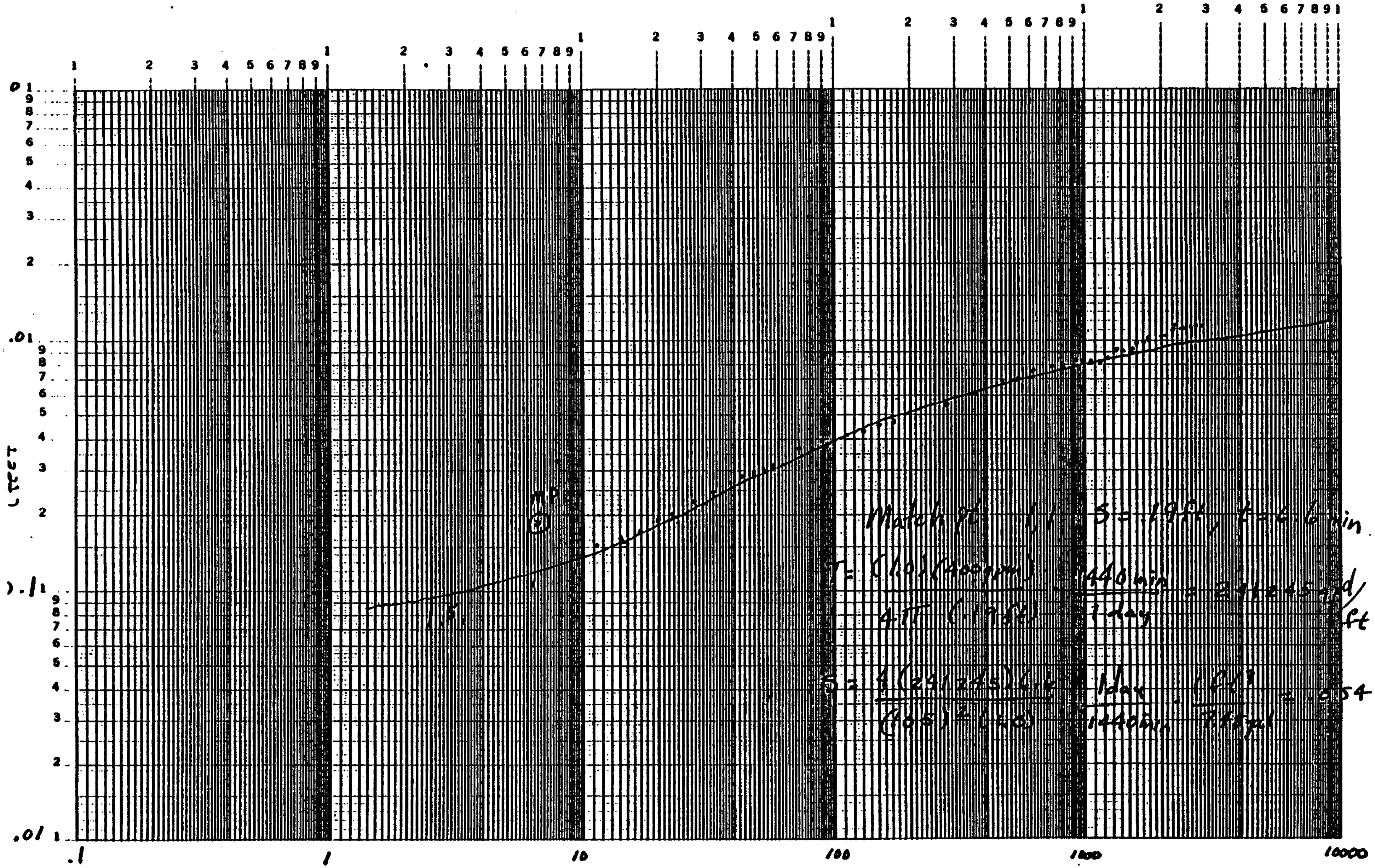
Alluvium pumptest
5/21-28/82

K•E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

Well SE-1

r = 105.0 ft.



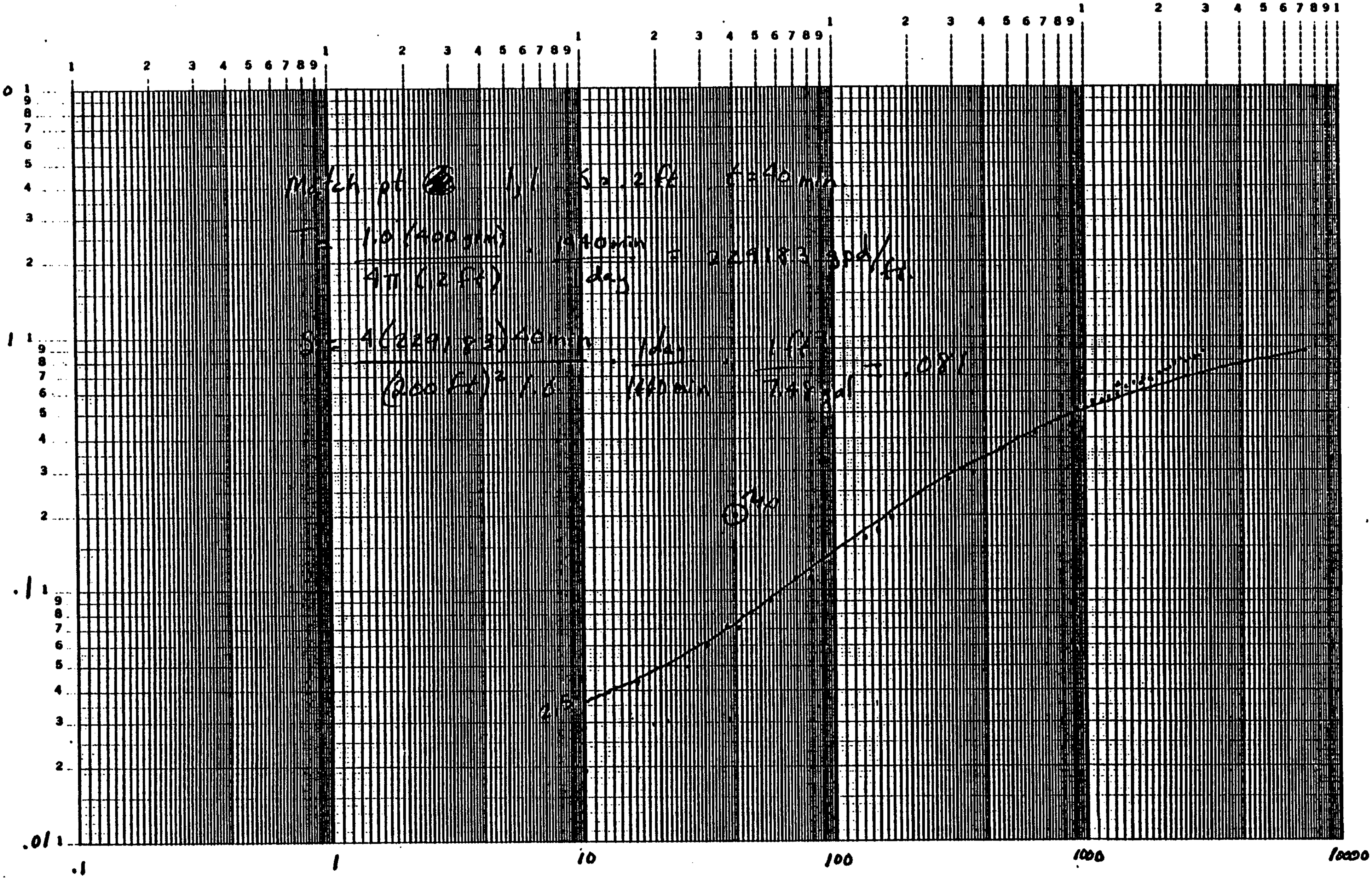
Alluvium pump test
5/26-28/82

K·E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

Well 669

r = 200 ft



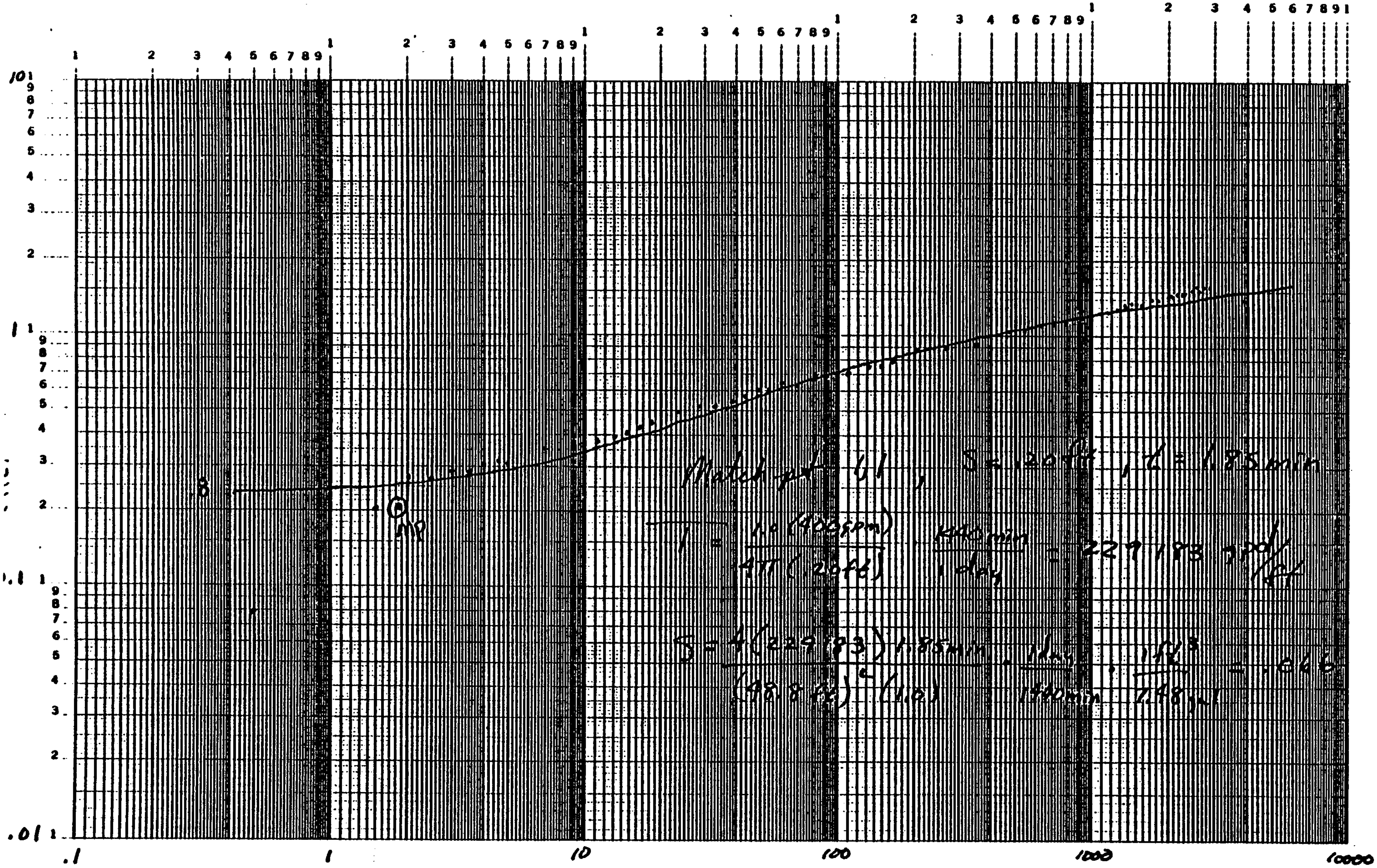
Alluvium Pumptest
5/26-28/82

K•E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN USA

46 7522

Well
13-B

r = 48.8 ft.

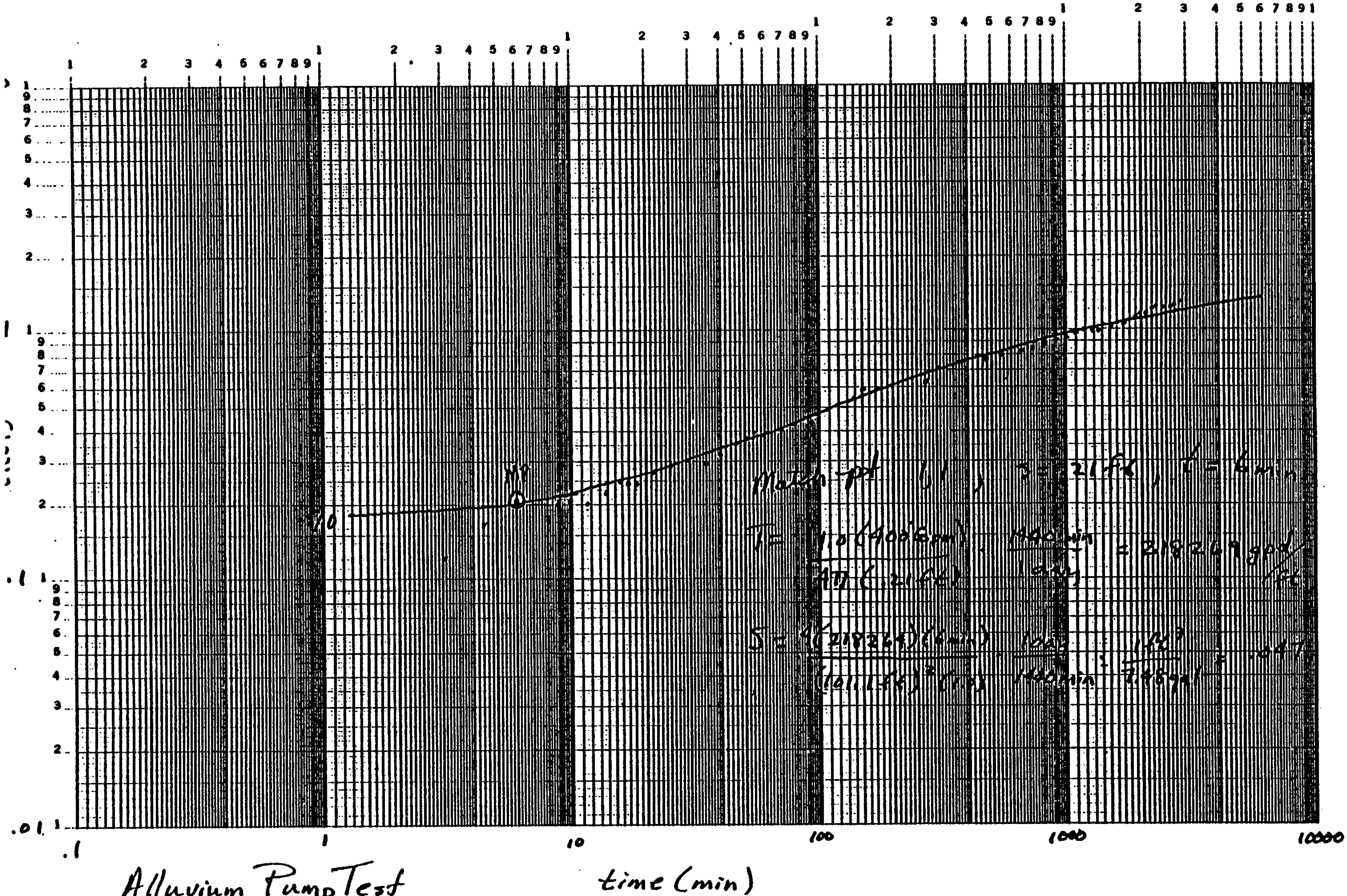


time (min)

Alluvium Pump Test
5/26-28/82

46 7522

Well 13-C r = 101.1



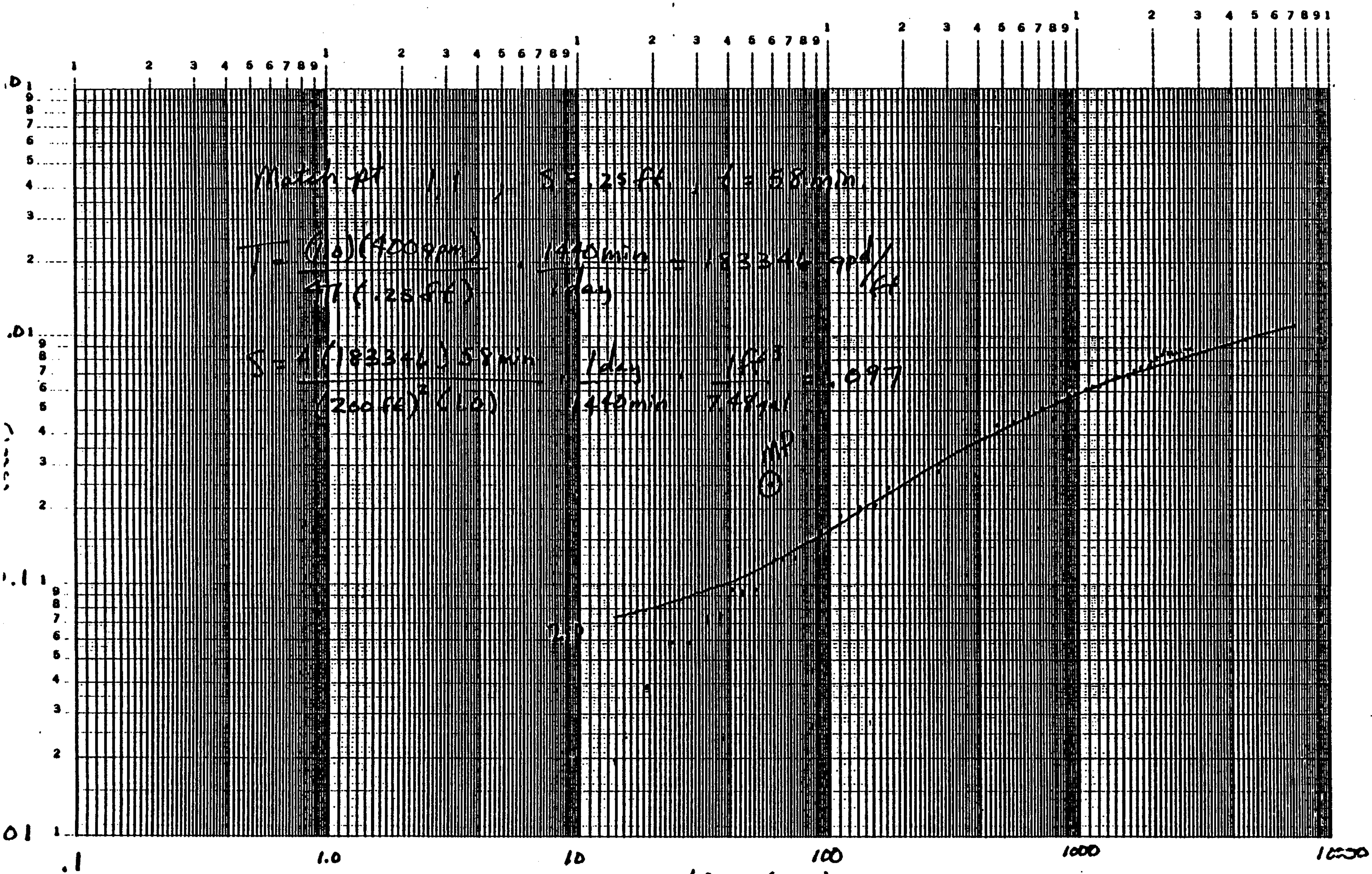
Alluvium Pump Test
5/26-28/82

K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

Well 13-A

r = 200 ft



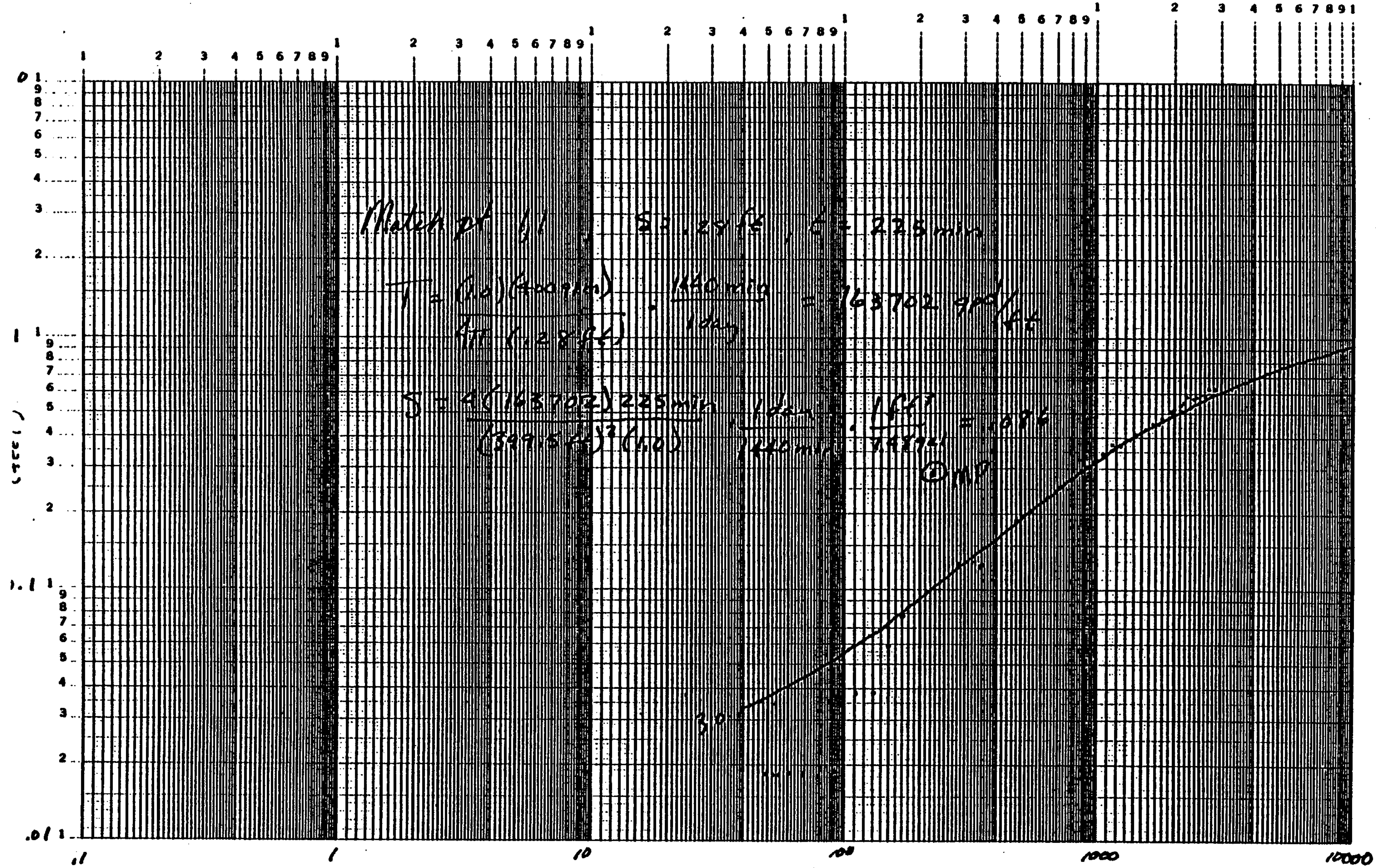
Alluvium Pump Test
5/26-28/82

K•E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

Well 82 - 14

r = 399.5



time (min)

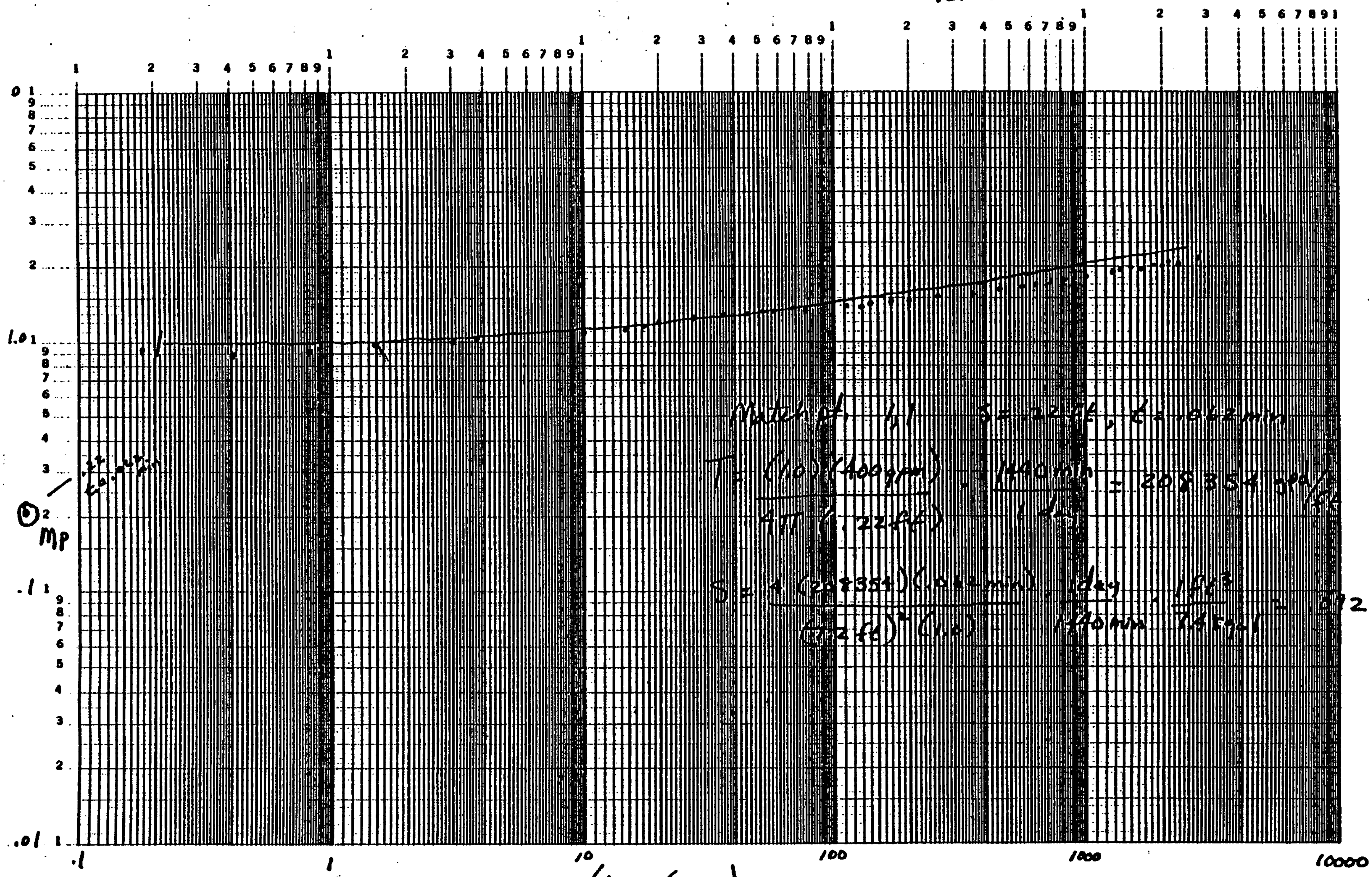
Alluvium Pump Test
5/26-28/82

K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

Well 12-D

r = 7.2 ft



Match pt. 1,1 $s = .22\ ft$, $t = .062\ min$

$$T = \frac{(1.0)(400\ gpm)}{4\pi\ (.22\ ft)} \cdot \frac{1440\ min}{1\ day} = 208354\ gpd/ft$$

$$S = \frac{4\ (208354)(.062\ min)}{(7.2\ ft)^2\ (1.0)} \cdot \frac{1\ day}{1440\ min} \cdot \frac{1\ ft^3}{7.48\ gal} = .092$$

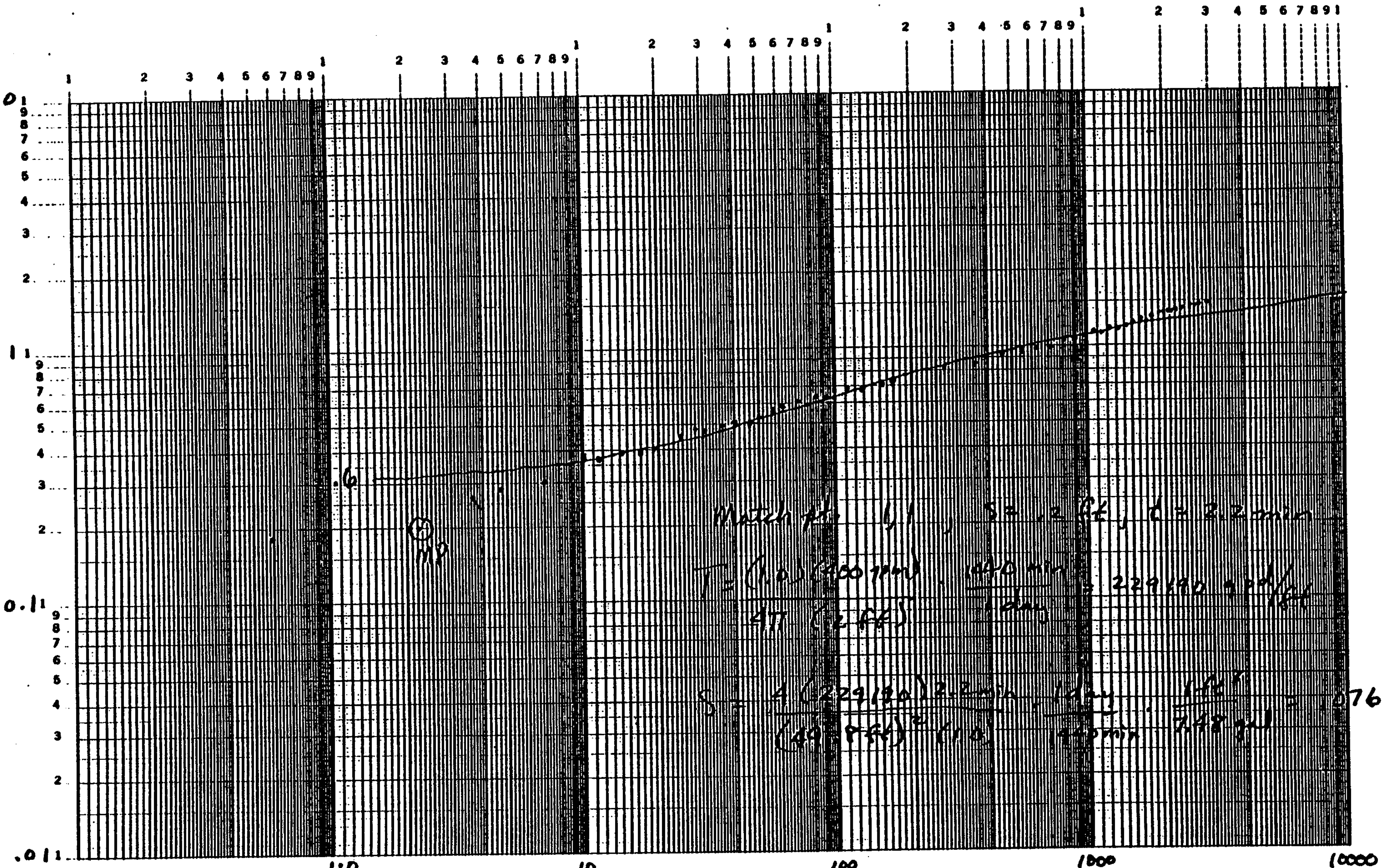
Alluvium Pumptest
5/26-28/87

K•E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

Well 12-B

r = 49.8 ft



Alluvium pump test
5/26-28/82

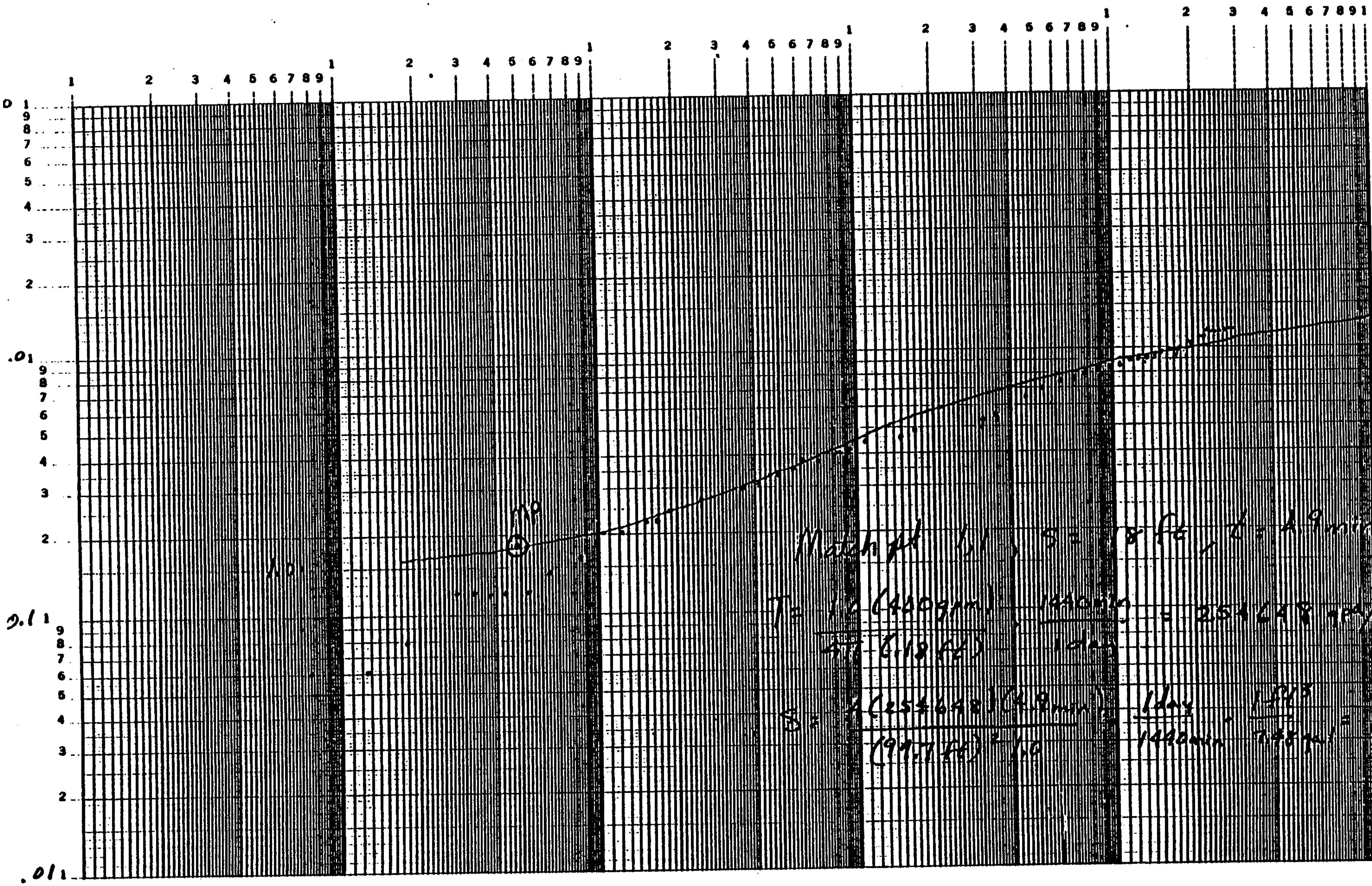
time (min)

K•E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

Well
12-C

r = 99.7 ft



Allvuium Pumptest
5/26-28/82

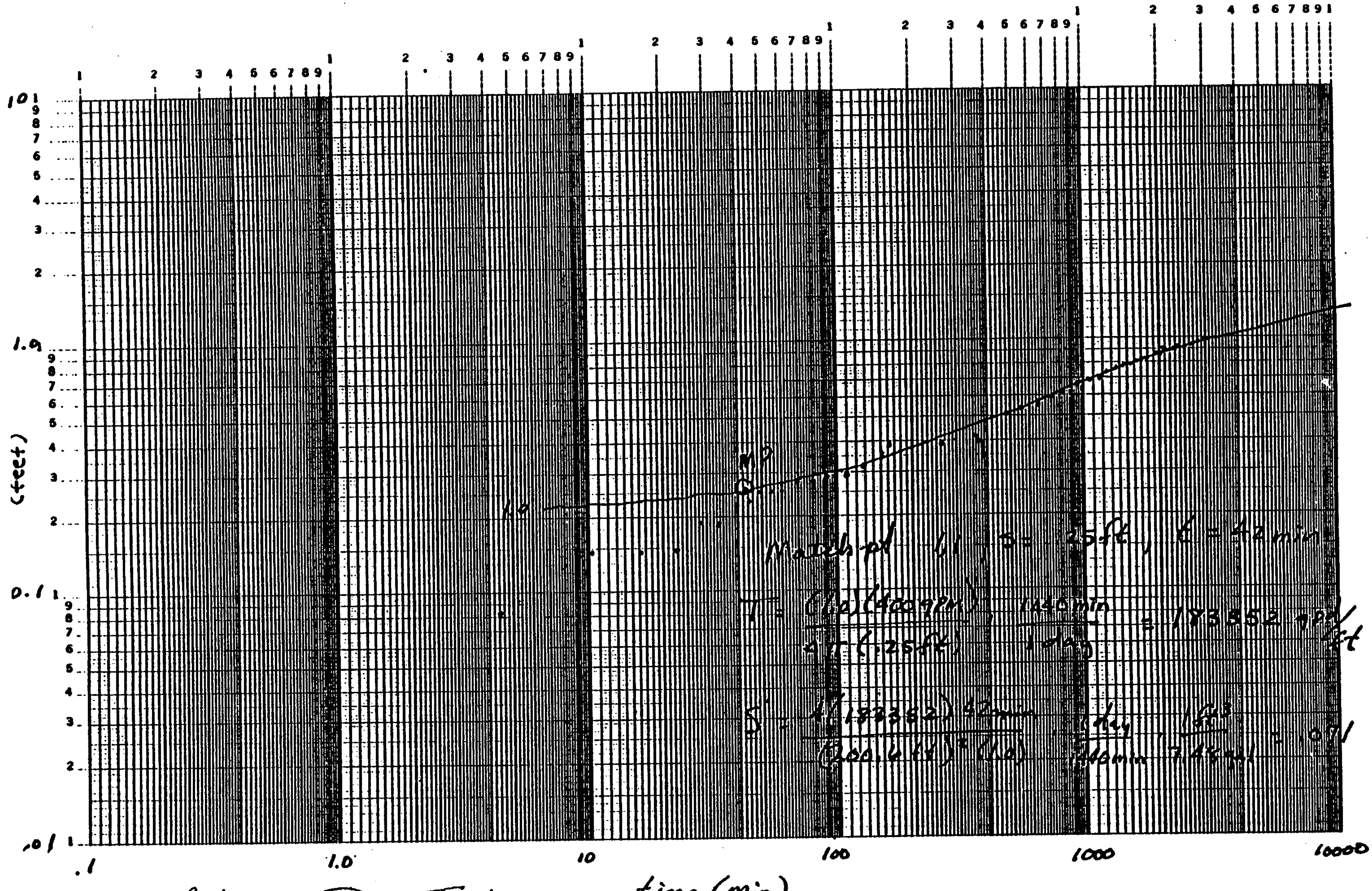
time (min

K·E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

Well 12-A

r = 200.6 ft.



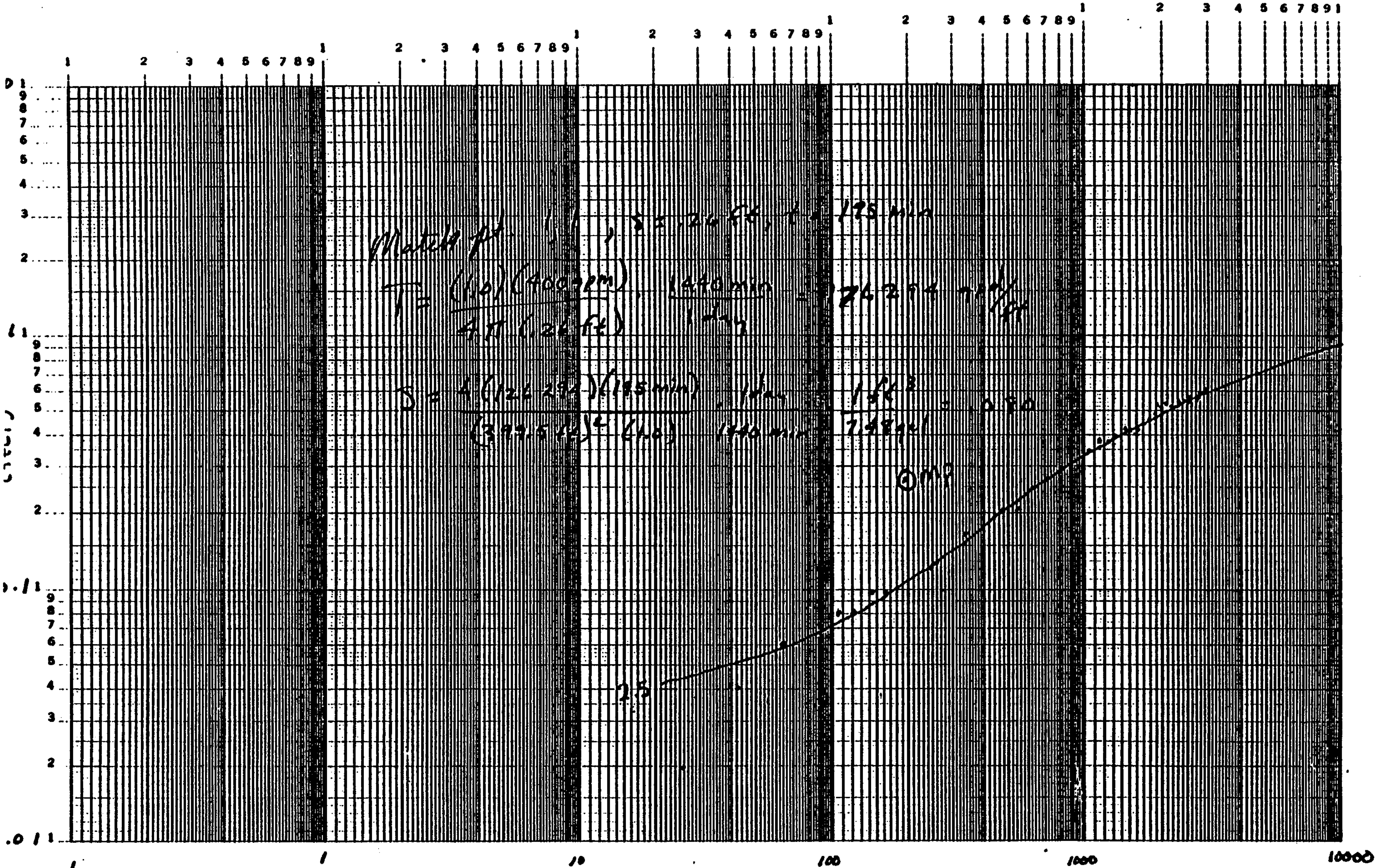
Alluvium Pump Test
5/26-28/82

K•E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

Well 82-12

r = 399.5 ft.



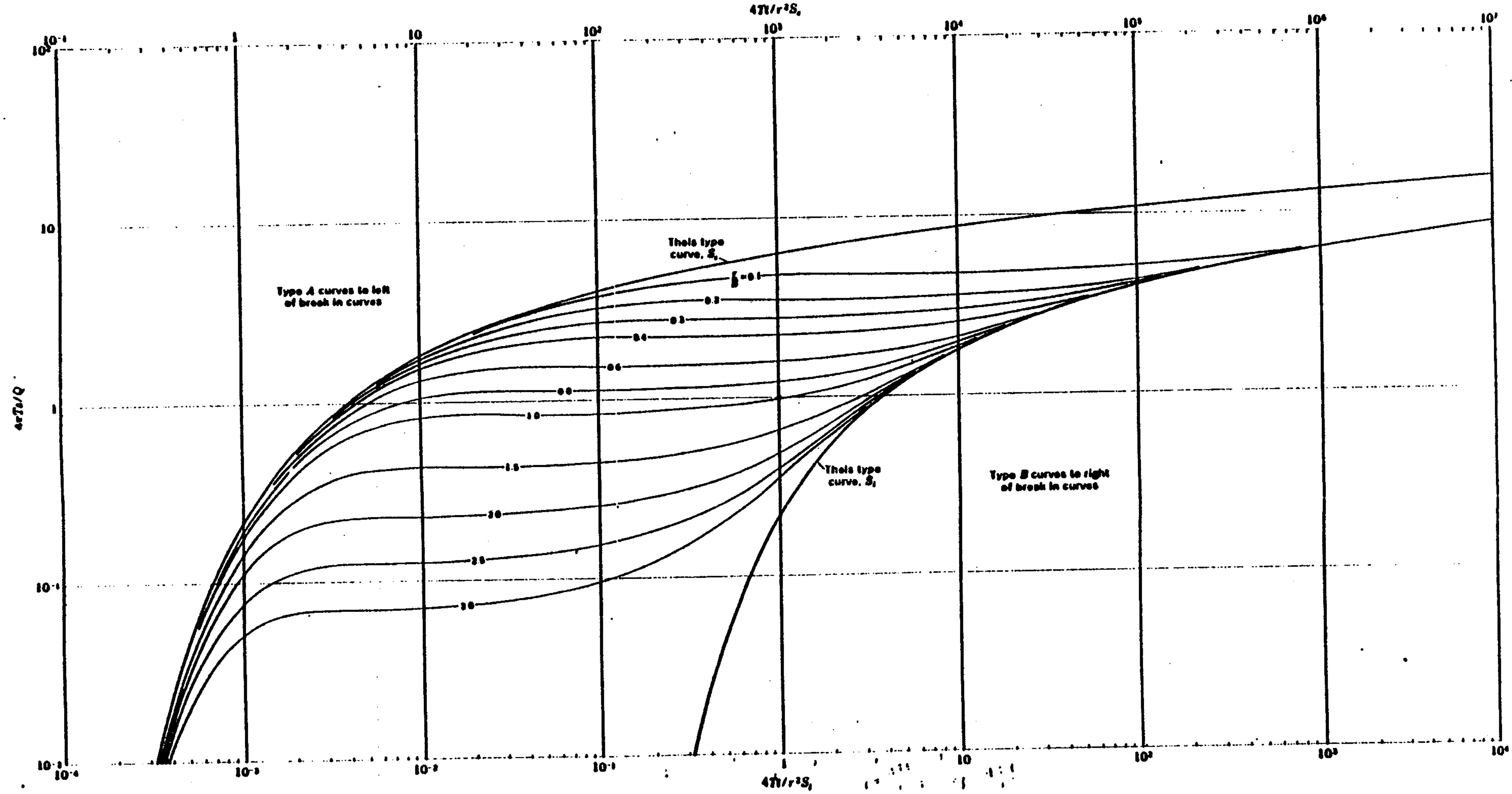
Match pt (1, 1), s = .26 ft, t = 185 min

$T = \frac{(1)(400\ gpm)}{4\pi(.26\ ft)} \cdot \frac{1440\ min}{1\ day} = 176294\ gpd/ft$

$S = \frac{4(176294)(185\ min)}{(399.5\ ft)^2(1440)} \cdot \frac{1\ day}{1440\ min} \cdot \frac{1\ ft^3}{7.48\ gal} = .080$

① MP

Alluvium Pump Test
5/26-28/82



DELAYED-YIELD TYPE CURVES

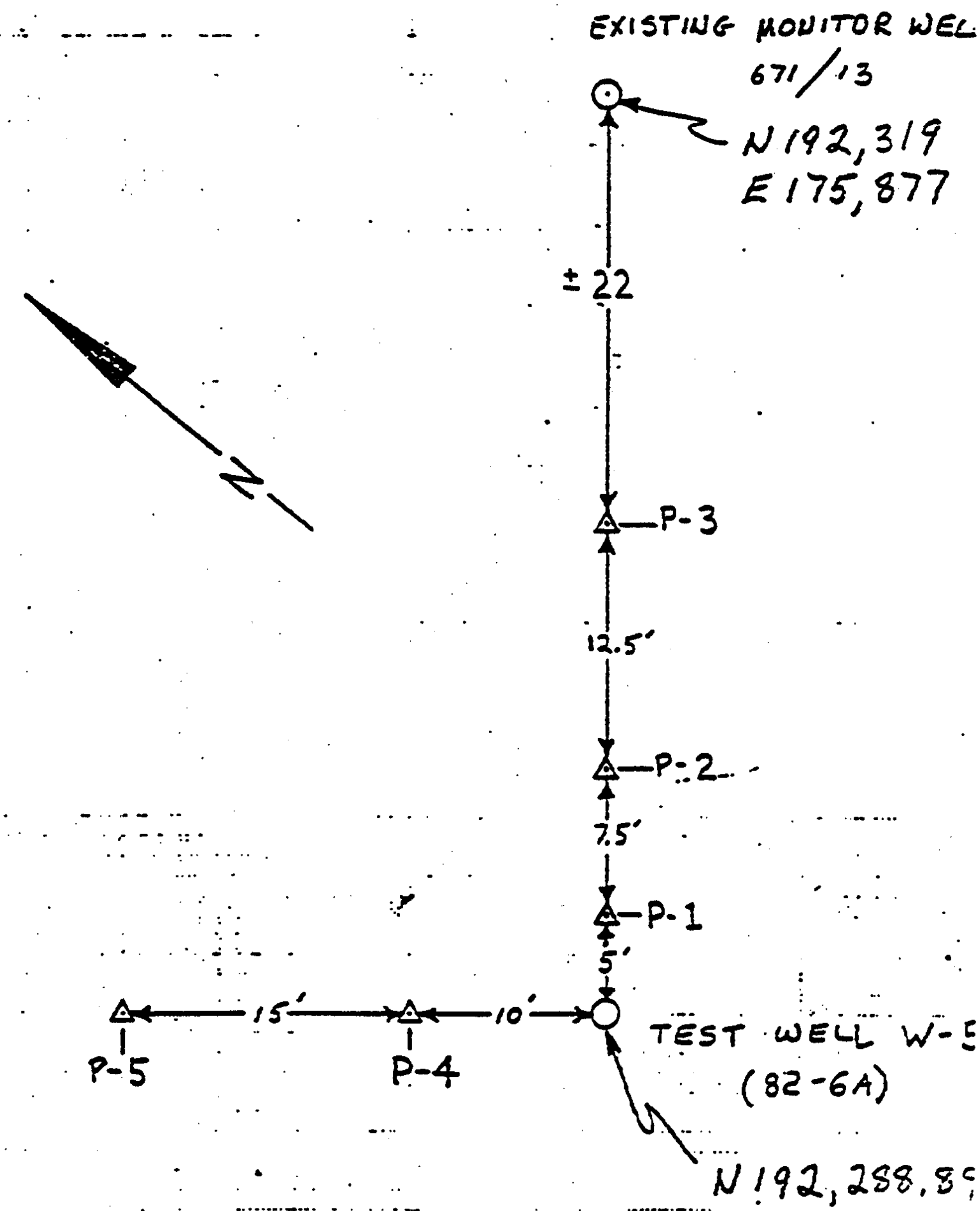
After Boulton (1963, fig. 1)

AQUIFER PUMP TEST DATA

WELL NO. W-5

PUMP TEST

WELL + PIEZOMETER LAYOUT



Δ = 2" diameter Piezometer

P-1 s vs. t

t (min)	s ft	r^2/t	t min	s ft	r^2/t
1	.05	25	110	.50	.227
2	.05	12.5	120	.56	.208
3	.05	8.33	180	.54	.139
4	.06	6.25	240	.64	.104
5	.06	5.00	300	.67	.083
6	.06	4.17	360	.66	.069
7	.07	3.57	420	.66	.060
8	.08	3.13	480	.71	.052
9	.09	2.78	540	.75	.046
10	.09	2.5	600	.76	.042
12	.11	2.08	720	.75	.035
14	.14	1.79	840	.76	.030
16	.17	1.56	960	.78	.026
18	.19	1.39	1080	.14	.023
20	.24	1.25	1200	.59	.0208
25	.26	1.0	1320	.79	.0187
30	.29	.83	1440	.80	.0174
35	.31	.71	1560	.81	.0160
40	.34	.625	1680	.82	.0149
45	.37	.56	1800	.82	.0139
50	.39	.50	1920	.83	.0130
55	.41	.45	2040	.87	.0123
60	.43	.42	2160	.84	.0116
70	.44	.357	2280	.86	.0110
80	.46	.313	2400	.85	.0104
90	.49	.278	2520	.87	.010
100	.49	.25	2640	.95	.0095
			2760	.91	.0091
			2880	.89	.0057

P-2 s vs. t

t min	s ft	s^2/t
1	0	
2	0	
3	0	
4	0	
5	0	
6	0	
7	0	
8	0	
9	0	
10	0	
12	0	
14	0	
16	0	
18	0	
20	0	
25	.18	6.25
30	.21	5.21
35	.21	4.46
40	.24	3.91
45	.24	3.47
50	.25	3.13
55	.27	2.84
60	.30	2.60
70	.33	2.23
80	.30	1.95
90	.34	1.74
100	.35	1.56
110	.37	1.42
120	.38	1.30

t min	s ft	s^2/t
180	.40	0.87
240	.37	0.65
300	.37	0.52
360	.45	0.43
420	.48	0.37
480	.45	0.33
540	.50	0.29
600	.50	0.26
720	.53	0.22
840	.54	0.19
960	.55	0.16
1080	.60	0.15
1200	.80	0.13
1320	.46	0.12
1440	.57	0.11
1560	.53	0.10
1680	.54	0.09
1800	.54	0.086
1920	.57	0.081
2040	.58	0.077
2160	.57	0.072
2280	.60	0.068
2400	.59	0.065
2520	.60	0.062
2640	.60	0.059
[illegible]	.64	0.057
[illegible]	.62	0.054

P-5

t min	S ft	r^2/t
1	0	
2	0	
3	0	
4	0	
5	0	
6	0	
7	0	
8	0	
9	0	
10	.02	62.5
12	.07	52.8
14	.02	44.64
16	.02	39.06
18	.04	34.72
20	.05	31.25
25	.07	25.00
30	.11	20.83
35	.11	17.86
40	.13	15.63
45	.14	13.89
50	.14	12.50
55	.17	11.36
60	.18	10.42
70	.19	8.93
80	.20	7.81
90	.22	6.94
100	.23	6.25
110	.24	5.68
120	.26	5.21
180	.31	3.47
240	.33	2.60
300	.36	2.08
360	.40	1.74

t min	s ft	r^2/t
420	.44	1.49
480	.44	1.30
540	.50	1.16
600	.52	1.04
720	.50	0.87
840	.48	0.74
960	.52	0.65
1080	.54	0.58
1200	.50	0.52
1320	.44	0.47
1440	.49	0.43
1560	.54	0.40
1680	.56	0.37
1800	.58	0.35
1920	.58	0.33
2040	.57	0.31
2160	.59	[illegible]
2280	.57	0.27
2400	.59	0.26
2520	.59	0.25
2640	.58	[illegible]
2760	.57	0.2[illegible]
2880	.63	[illegible]

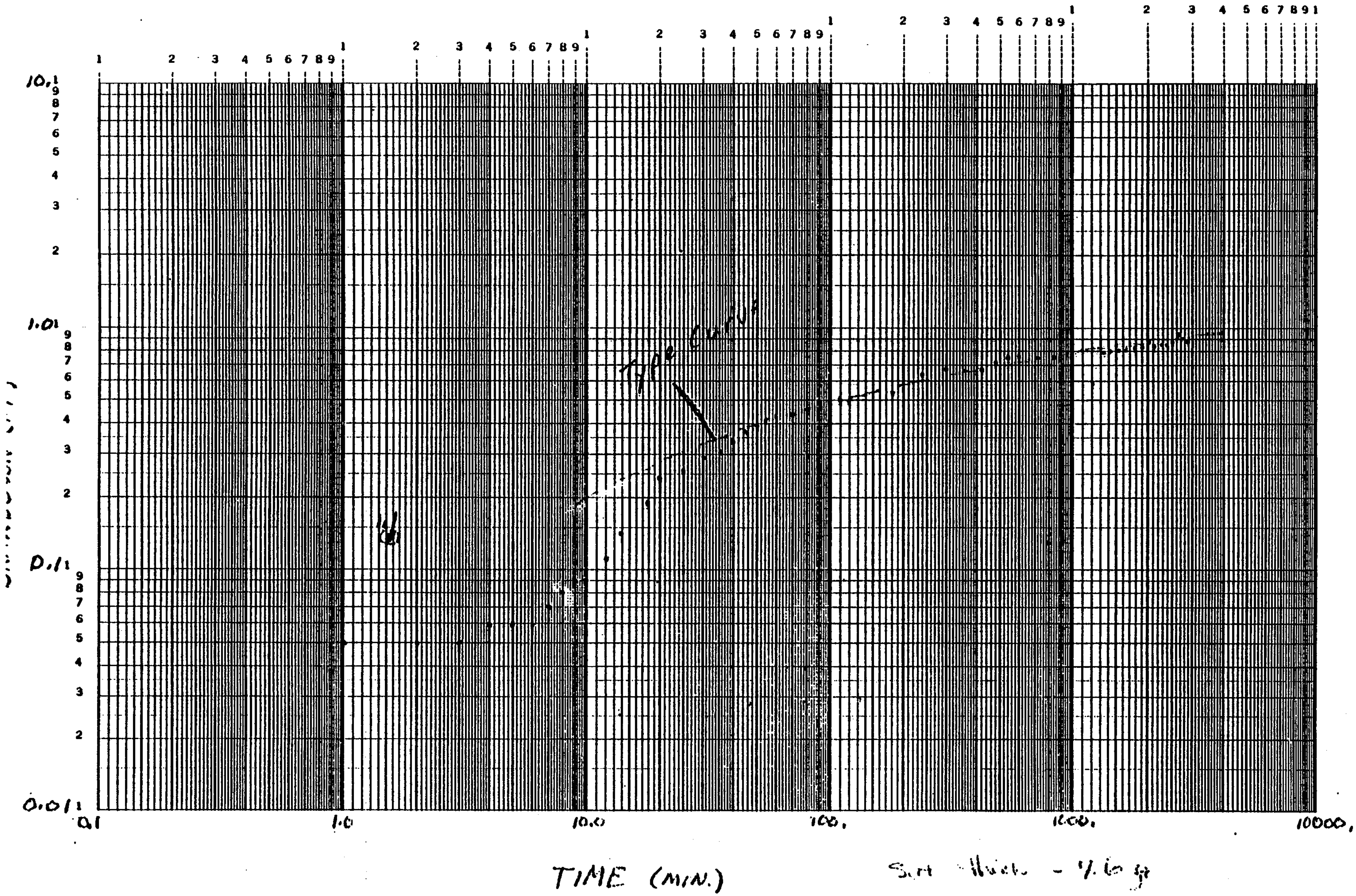
22-13

t min	s-ft	R^2/t	t min	s-ft	R^2/t
2	.04	1104.5	420	.41	5.26
4	.07	552.3	480	.40	4.60
6	.08	368	540	.45	4.09
8	.08	276	600	.45	3.68
10	.10	221	720	.44	3.07
12	.11	184	840	.22	2.63
14	.12	158	960	.33	2.30
16	.13	138	1080	.33	2.05
18	.14	123	1200	.28	1.84
20	.15	110	1320	.28	1.67
25	.17	88	1440	.26	1.53
30	.18	73.6	1560	.48	1.42
35	.18	63.1	1680	.49	1.31
40	.19	55.2	1800	.51	1.23
45	.20	49.1	1920	.54	1.15
50	.22	44.2	2040	.54	1.08
55	.22	40.2	2160	.54	1.02
60	.22	36.8	2280	.54	.969
70	.22	31.6	2400	.52	.920
80	.23	27.6	2520	.44	.877
90	.24	24.5	2640	.47	.837
100	.25	22.1	2760	.47	.800
110	.27	20.1	2880	.44	.767
120	.27	18.4			
180	.29	12.3			
240	.34	9.20			
300	.39	7.36			
360	.40	6.14			

K&E LOGARITHMIC 3 x 5 CYCLES KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

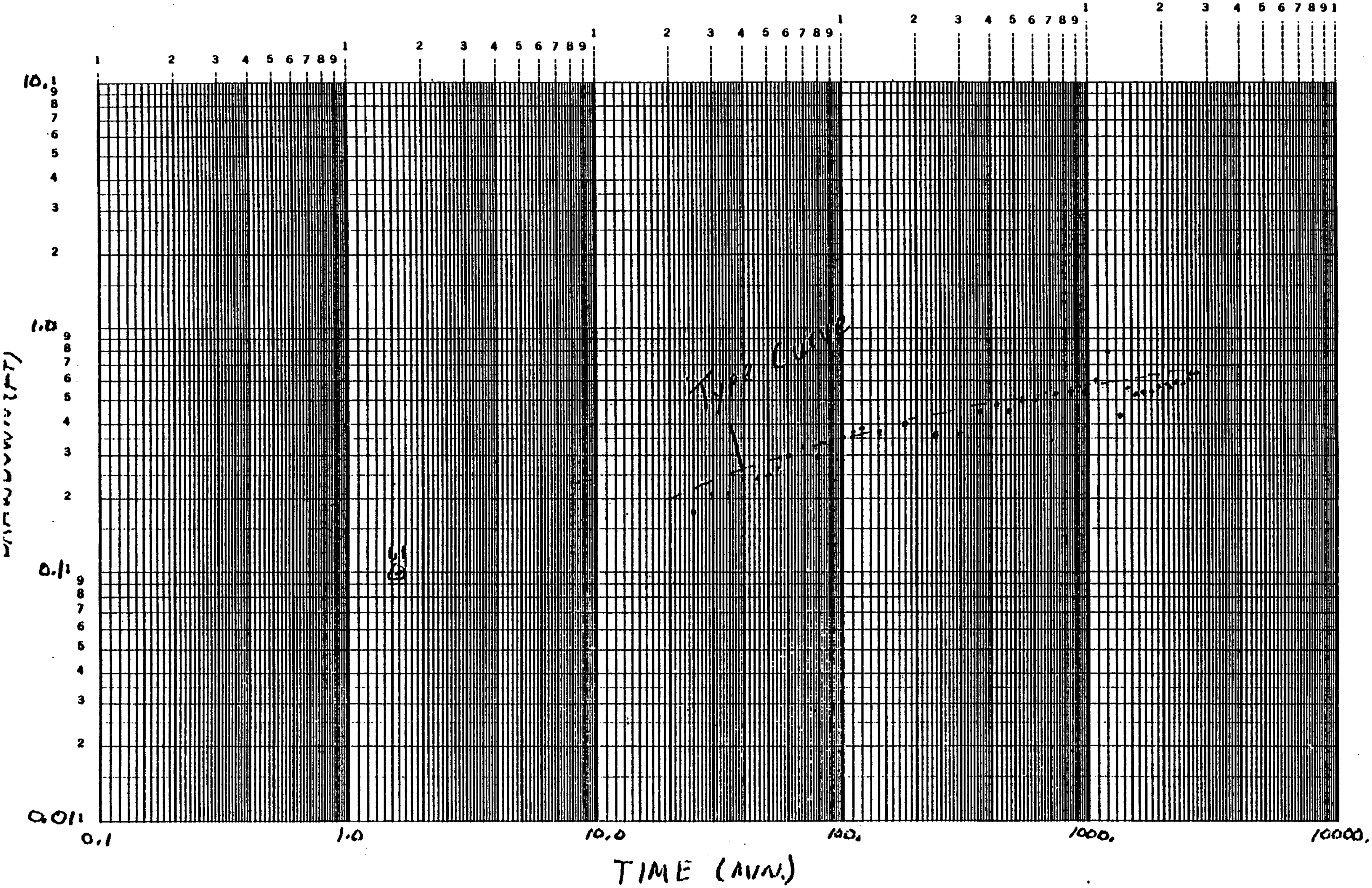
P-1 r=5ft.



K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

P-2 r = 12.5 ft



OMAHA DISTRICT | COMPUTATION SHEET | CORPS OF ENGINEERS

PROJECT RMA 71-5 PUMP TEST	SHEET NO.	OF
ITEM ANALYSIS OF PUMP TEST DATA DRAWDOWN VS. r^2/t FOR P1	BY BECKER	DATE
	CHKD. BY	DATE

P-1

$W(u) = 1$ $Q = 33.5$ gpm $s = .134$ ft $b = 7.6$ ft

$u = 1$ $r = 5$ ft $r^2/t = 15.6$ ft^2/min

$$T = \frac{Q}{4\pi s} W(u) = \frac{33.5 \text{ gpm}}{4\pi (.134 \text{ ft})} \cdot (1) \cdot 1440 \frac{\text{min}}{\text{day}} = 28648 \text{ gpd/ft}$$

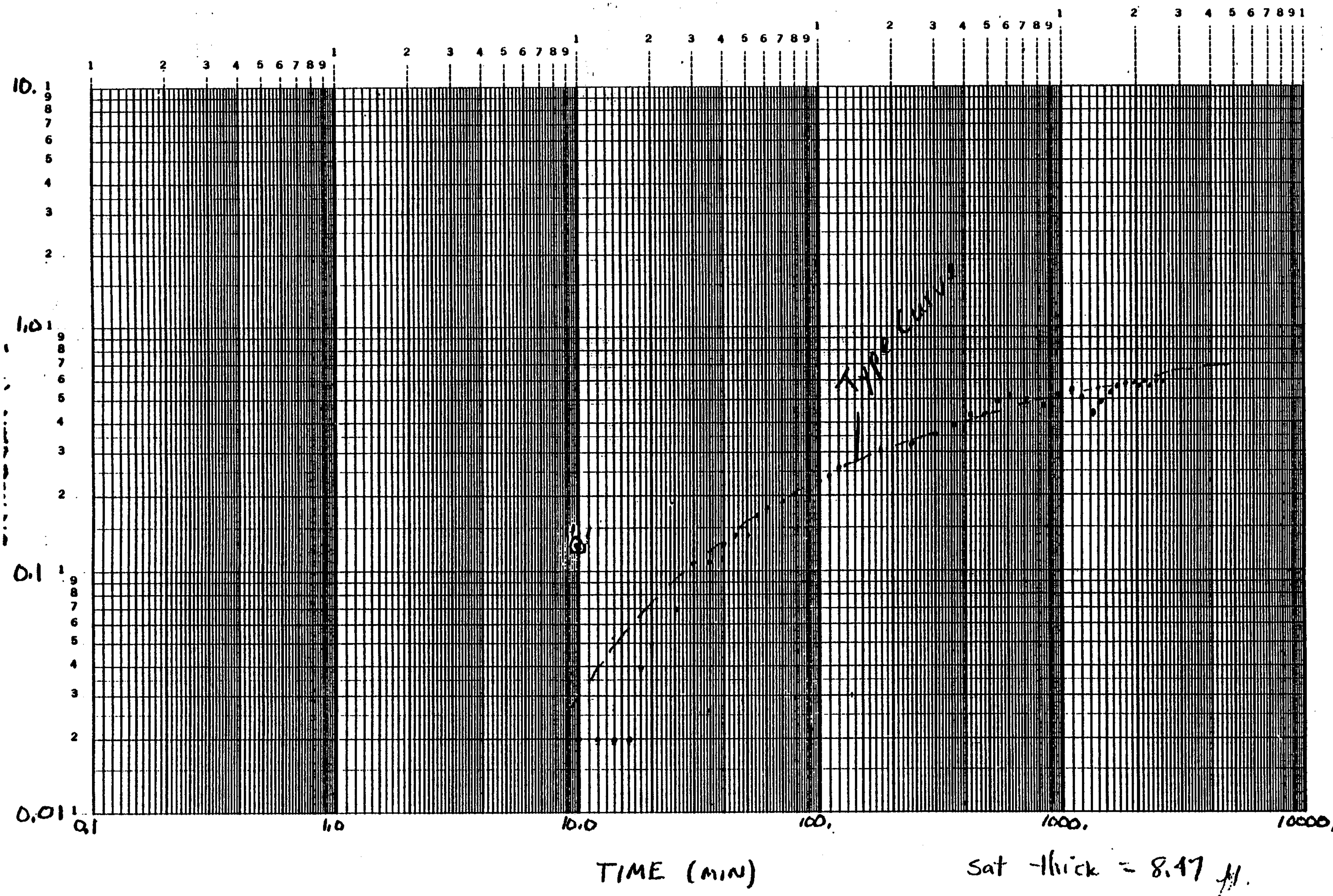
$$S = \frac{u\,4\,T}{r^2/t} = (1)\,\frac{28648 \text{ gpd/ft}}{} \cdot \frac{1}{15.6 \text{ ft}^2/\text{min}} \cdot \frac{1 \text{ day}}{1440 \text{ min}} \cdot \frac{1 \text{ ft}^3}{7.48 \text{ gal}}$$

$$= .68$$

$$K = \frac{T}{b} = \frac{28648 \text{ gpd/ft}}{7.6 \text{ ft}} \cdot \frac{1 \text{ ft}^3}{7.48 \text{ gal}} = 504 \text{ ft/day}$$

K+E LOGARITHMIC 3 x 5 CYCLES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 7522

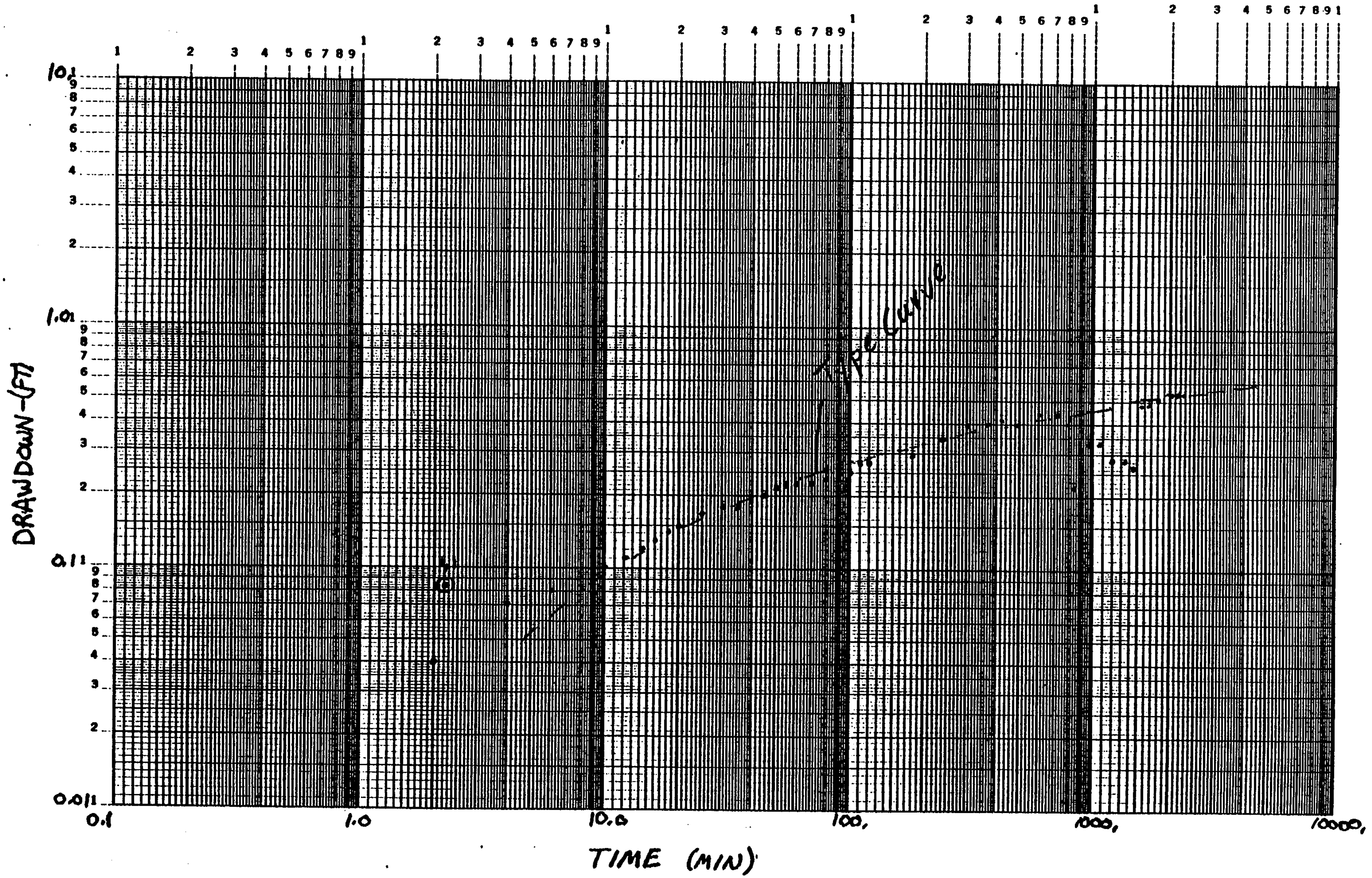
P-5 r = 25. ft.



Sat thick = 8.47 ft.

46 7522

22-13 r=17ft



RECOVERY P-1

t min	t' min	t/t'	s' ft
2880	0	0	
2881	1	2881	.88
2882	2	1441	.87
2883	3	961	.86
2884	4	721	.86
2885	5	577	.86
2886	6	481	.85
2887	7	412.43	.84
2888	8	361	.84
2889	9	321	.83
2890	10	289	.82
2892	12	241	.81
2894	14	206.71	.81
2896	16	181	.81
2898	18	161	.80
2900	20	145	.79
2905	25	116.2	.77
2910	30	97	.75
2915	35	83.29	.73
2920	40	73	.72
2925	45	65	.70
2930	50	58.6	.70
2935	55	53.36	.69
2940	60	49	.66
2950	70	42.14	.64
2960	80	37	.62
2970	90	33	.59
2980	100	29.8	.57

RECOVERY P-1

t min	t' min	t/t'	s'
2990	110	27.18	.56
3000	120	25	.54
3060	180	17	.47
3120	240	13	.39
3180	300	10.6	.36
3240	360	9	.32
3300	420	7.86	.31
3360	480	7	.31
3420	540	6.33	.31
4020	1140	3.53	.20

P-2 RECOVERY

t min	t' min	t/t'	s' ft
2880	0		.62
2881	1	2881	.60
2882	2	1441	.57
2883	3	961	.58
2884	4	721	"
2885	5	577	"
2886	6	481	"
2887	7	412	.56
2888	8	361	.56
2889	9	321	.56
2890	10	289	.55
2892	12	241	.55
2894	14	207	.54
2896	16	181	.55
2898	18	161	.57
2900	20	145	"
2905	25	116	.51
2910	30	97	"
2915	35	83	.48
2920	40	73	"
2925	45	65	.45
2930	50	59	.44
2935	55	53	.42
2940	60	49	.41
2950	70	42	.37
2960	80	37	.36
2970	90	33	.33
2980	100	30	.33

P-2 RECOVERY

t min	t' min	t/t'	s' ft
2990	110	27	.31
3000	120	25	.31
3060	180	17	.25
3120	240	13	.25
3180	300	11	.23
3240	360	9	.23
3300	420	7.86	.23
3360	480	7	.23
3420	540	6.3	.23
4020	1140	3.5	.17

P-4 RECOVERY

t min	t' min	t/t'	s' ft
2881	1	2881	.68
2882	2	1441	-
2883	3	961	.67
2884	4	721	.66
2885	5	577	.66
2886	6	481	-
2887	7	412	.64
2888	8	361	.62
2889	9	321	.62
2890	10	289	.60
2892	12	241	.59
2894	14	206	.58
2896	16	181	.58
2898	18	161	.56
2900	20	145	.53
2905	25	116	.52
2910	30	97	.48
2915	35	83	.48
2920	40	73	.43
2925	45	65	.43
2930	50	59	.41
2935	55	53	.40
2940	60	49	.39
2950	70	42	.36
2960	80	37	.33
2970	90	33	.33
2980	100	30	.31
2990	110	27	.30
3000	120	25	.29

P-4 RECOVERY CONT

t min	t' min	t/t'	s' ft
3060	180	17	.26
3120	240	13	.25
3180	300	11	.24
3240	360	9	.22
3300	420	7.9	.21
3360	480	7	.21
3420	540	6.3	.21
3900	1020	3.5	.11

RECOVERY P-5

t min	t' min	t/t'	s' ft
2880	0		
2881	1	2881	
2882	2	1441	.61
2883	3	961	
2884	4	721	
2885	5	577	
2886	6	481	.61
2887	7	412	
2888	8	361	
2889	9	321	
2890	10	289	
2892	12	241	.47
2894	14	206	
2896	16	181	.43
2898	18	161	.40
2900	20	145	.37
2905	25	116	.36
2910	30	97	.32
2915	35	83	.31
2920	40	73	.33
2925	45	65	.35
2930	50	59	.30
2935	55	53	.27
2940	60	49	.26
2950	70	42	.23
2960	80	37	.22
2970	90	33	.19
2980	100	30	.17
2990	110	27.2	.14
3000	120	25	.14

RECOVERY P-5

t min	t' min	t/t'	s' (ft)
3060	180	17	.11
3120	240	13	.10
3180	300	10.6	.06
3240	360	9	.05
3300	420	7.9	.02
3360	480	7	0
3420	540	6.33	0
3900	1020	3.53	-.09

OMAHA DISTRICT — COMPUTATION SHEET — CORPS OF ENGINEERS

PROJECT RMA - W-5 PUMP TEST		SHEET NO.	OF
ITEM ANALYSIS OF PUMP TEST DATA S vs. t		BY BECKER	DATE
P-2, 22-13, P-5		CHKD. BY	DATE

P-2: $Q = 33.5\,gpm$ $s = .1\,ft$ $b = 7.4\,ft$

$W(u) = u = 1$ $r = 12.5\,ft$ $t = 1.6\,min$

$$T = \frac{Q}{4\pi s}(W(u)) = \frac{33.5\,gpm}{4\pi(.1\,ft)}(1)\,1440\,\frac{min}{day} = 38388\,gpd/ft$$

$$K = \frac{T}{b} = \frac{38388\,gpd/ft}{7.4\,ft} \cdot \frac{1\,ft^3}{7.48\,gal} = 693\,ft/day$$

$$S = \frac{u\,4Tt}{r^2} = \frac{(1)\,4(38388\,gpd/ft)\,1.6\,min}{(12.5\,ft)^2}, \frac{1\,day}{1440\,min}, \frac{1\,ft^3}{7.48}$$

$$= .146$$

22-13:

$W(u) = 1$ $Q = 33.5\,gpm$ $s = .084\,ft$ $b = 7.2\,ft$

$u = 1$ $r = 47\,ft$ $t = 1.2\,min$

$$T = \frac{Q}{4\pi s}W(u) = \frac{33.5\,gpm}{4\pi\,.084\,ft}(1) \cdot 1440\,\frac{min}{day} = 45700.\,gpd/ft$$

$$K = \frac{T}{b} = \frac{45700\,gpd/ft}{7.2\,ft} \cdot \frac{1\,ft^3}{7.48\,gal} = 848.\,ft/day$$

$$S = \frac{u\,4Tt}{r^2} = \frac{(1)\,4\,(45700\,gpd/ft)\,1.2\,min}{(47\,ft)^2}, \frac{1\,day}{1440\,min}, \frac{1\,ft^3}{7.48\,gal}$$

$$= .009$$

P-5

$W(u) = 1$ $Q = 33.5\,gpm$ $s = .13\,ft$ $b = 8.47\,ft$

$u = 1$ $r = 25.0\,ft$ $t = 10.0\,min$

$$T = \frac{Q}{4\pi s}W(u) = \frac{33.5\,gpm\,(1)}{4\pi(.13\,ft)} \cdot 1440\,\frac{min}{day} = 29529\,gpd/ft$$

$$K = \frac{T}{b} = \frac{29529\,gpd/ft}{8.47\,ft} \cdot \frac{1\,ft^3}{7.48\,gal} = 466\,ft/day$$

$$S = u\,\frac{4Tt}{r^2} = \frac{(1)\;4\,(29529\,gpd/ft)(10.0\,min)}{(25\,ft)^2} \cdot \frac{1\,day}{1440} \cdot \frac{1\,ft^3}{7.48\,gal}$$

$$= .175$$

MRO FORM 1550
1 OCT 72

Page ____

OMAHA DISTRICT | COMPUTATION SHEET | CORPS OF ENGINEERS

PROJECT RMA – W-5 PUMP TEST | SHEET NO. | OF

ITEM ANALYSIS OF PUMP TEST DATA | BY BECKER | DATE

DRAWDOWN VS. r^2/t FOR 22-13, P-2, P-5 | CHKD. BY | DATE

22-13:

$W(u)=1$ $Q=33.5$ gpm $s=.092$ ft $b=7.2$ ft

$u=1$ $r=41$ ft $r^2/t=750$ ft²/min

$$T=\frac{Q}{4\pi s}W(u)=\frac{33.5\text{ gpm}}{4\pi(.092\text{ ft})}(1)\cdot 1440\frac{\text{min}}{\text{day}}=41726\text{ gpd/ft}$$

$$K=\frac{T}{b}=\frac{41726\text{ gpd/ft}}{7.2\text{ ft}}\cdot\frac{1\text{ ft}^3}{7.48\text{ gal}}=774.\text{ ft/day}$$

$$S=\frac{u\,4Tt}{r^2}=(1)(4)41726\text{ gpd/ft}\left(\frac{1}{750\text{ ft}^2/\text{min}}\right)\cdot\frac{1\text{ day}}{1440\text{ min}}\cdot\frac{1\text{ ft}^3}{7.48\text{ gal}}$$

$=.02$

P-2:

$W(u)=1$ $Q=33.5$ gpm $s=.09$ ft $b=7.4$ ft

$u=.1$ $r=12.5$ ft $r^2/t=10.6$ ft²/min

$$T=\frac{Q}{4\pi s}W(u)=\frac{33.5\text{ gpm}}{4\pi\,.09}(1)\cdot 1440\frac{\text{min}}{\text{day}}=42653\text{ gpd/ft}$$

$$K=\frac{T}{b}=\frac{42653\text{ gpd/ft}}{7.4\text{ ft}}\cdot\frac{1\text{ ft}^3}{7.48\text{ gal}}=770\text{ ft/day}$$

$$S=\frac{u\,4Tt}{r^2}=(1)(4)(42653\text{ gpd/ft})\left(\frac{1}{10.6\text{ ft}^2/\text{min}}\right)\cdot\frac{1\text{ day}}{1440\text{ min}}\cdot\frac{1\text{ ft}^3}{7.48\text{ gal}}$$

$=.148$

P-5

$W(u)=1$ $Q=33.5$ gpm $s=.125$ ft $b=8.47$ ft

$u=1$ $r=25$ ft $r^2/t=61$ ft²/min

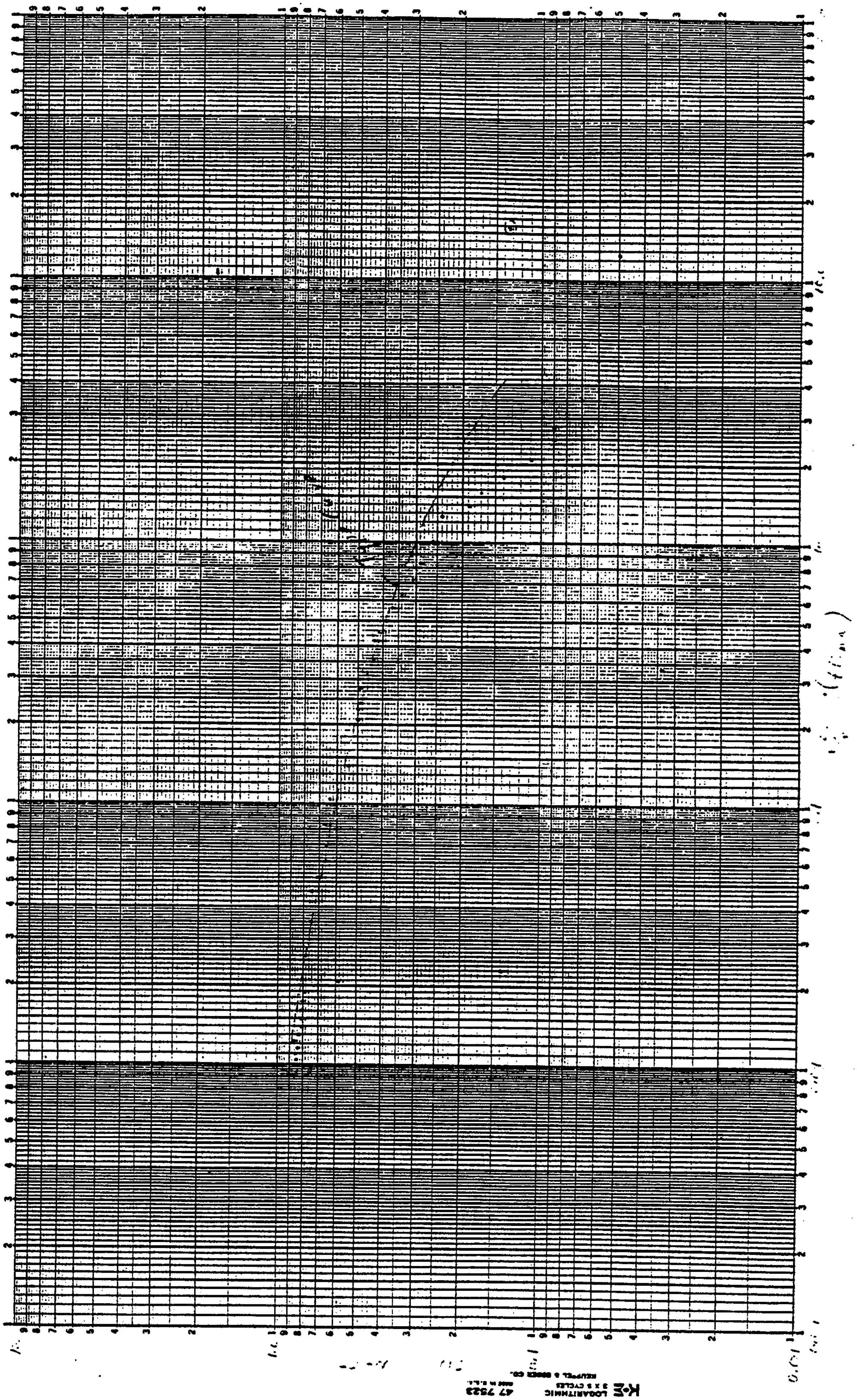
$$T=\frac{Q}{4\pi s}W(u)=\frac{33.5}{4\pi(.125\text{ ft})}(1)\cdot 1440\frac{\text{min}}{\text{day}}=30711\text{ gpd/ft}$$

$$K=\frac{T}{b}=\frac{30711\text{ gpd/ft}}{8.47\text{ ft}}\cdot\frac{1\text{ ft}^3}{7.48\text{ gal}}=485\text{ ft/day}$$

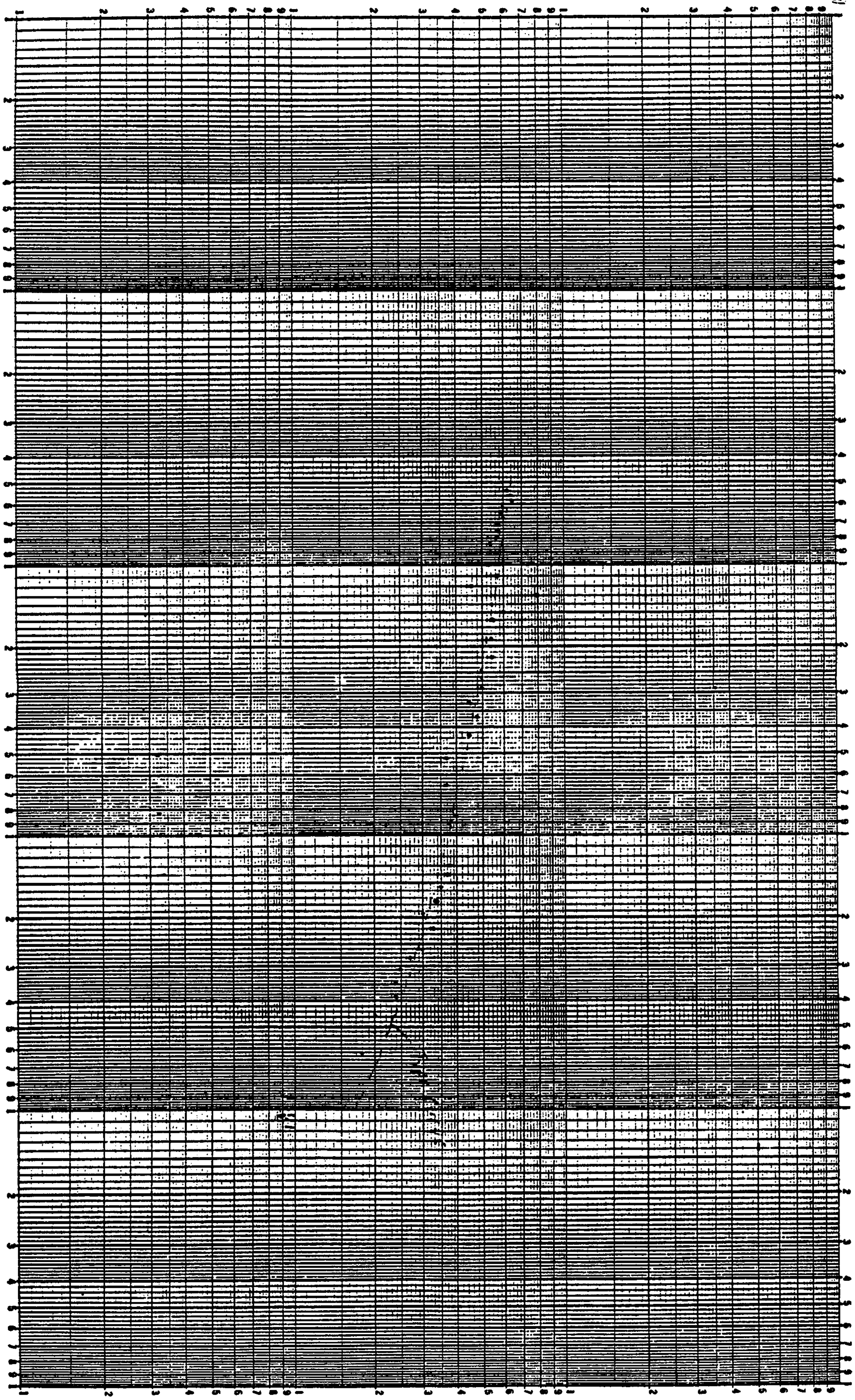
$$S=\frac{u\,4Tt}{r^2}=(1)4(30711\text{ gpd/ft})\cdot\left(\frac{1}{61\text{ ft}^2/\text{min}}\right)\cdot\frac{1\text{ day}}{1440\text{ min}}\cdot\frac{1\text{ ft}^3}{7.48\text{ gal}}$$

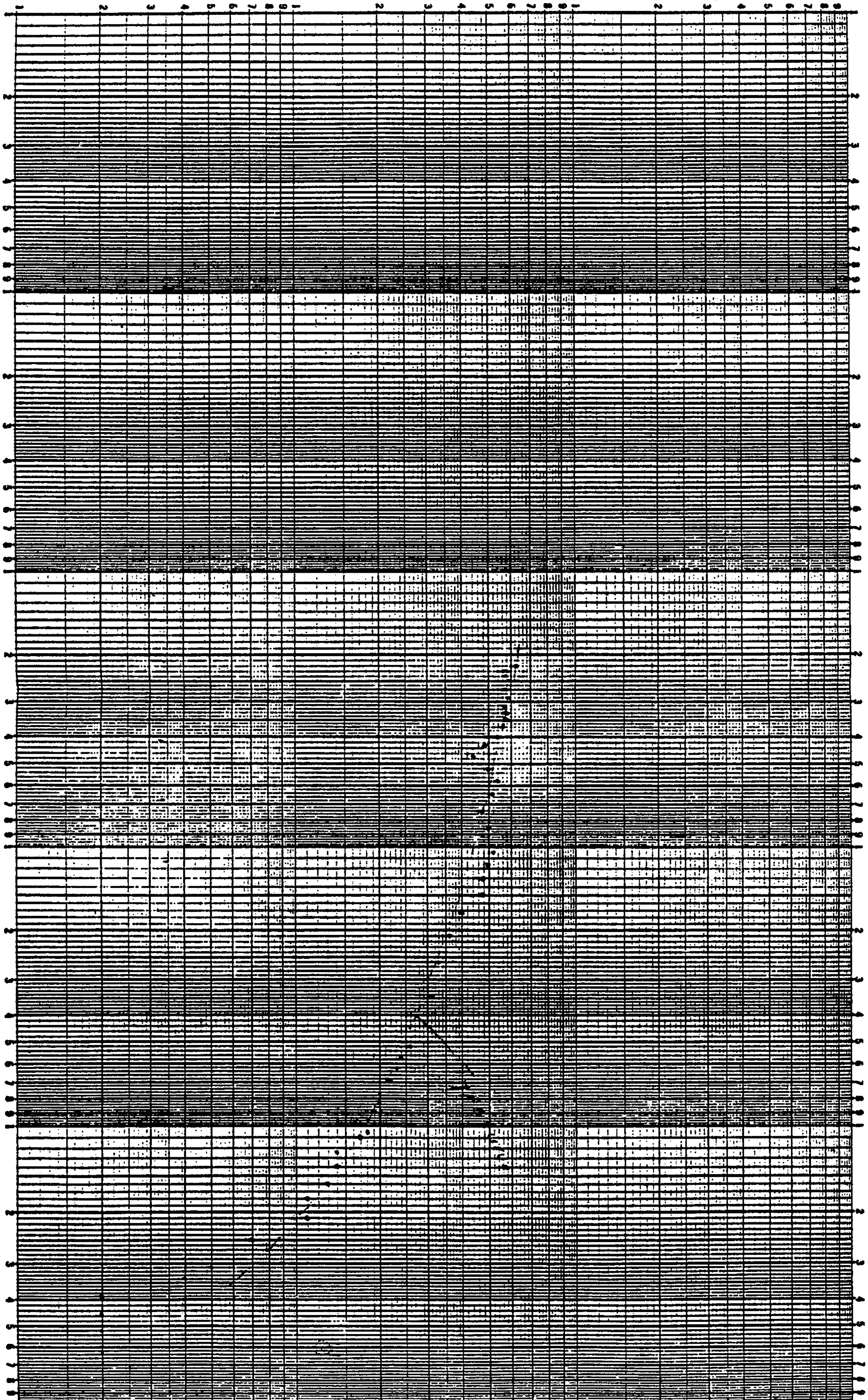
$=.187$

MRO FORM 1550
1 OCT 72

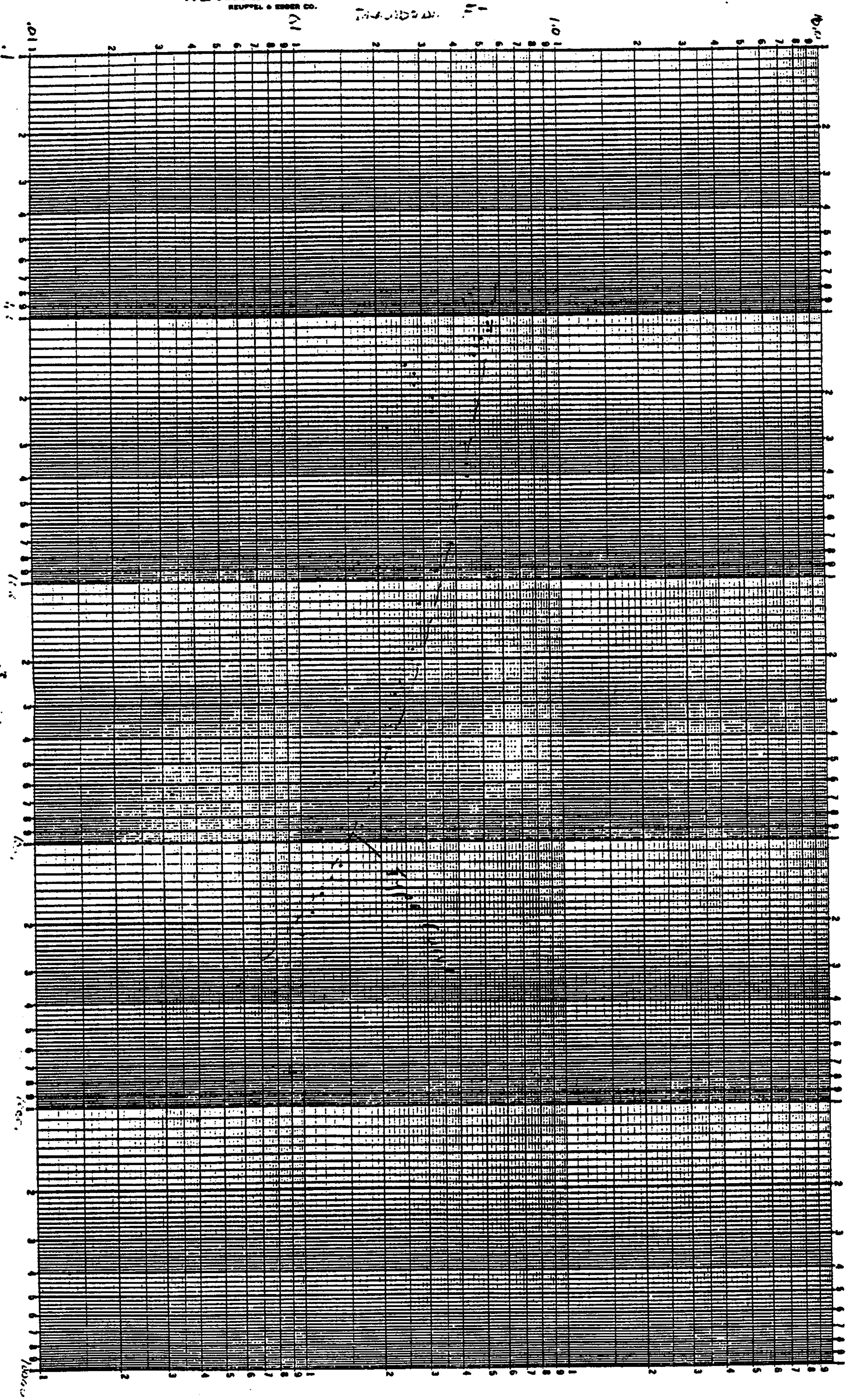


K+E LOGARITHMIC 47 7523
3 X 5 CYCLES MADE IN U.S.A.
KEUFFEL & ESSER CO.





K+E LOGARITHMIC 47 7523
3 X 5 CYCLES MADE IN U.S.A.
KEUFFEL & ESSER CO.



OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA - W-5 Pump Test		SHEET NO.	OF
ITEM Analysis of Pump Test Data s vs. t Well F-1		BY KREBS	DATE
		CHKD. BY	DATE

$W(u) = 1$ $Q = 33.5$ gpm $s = 0.138$ ft $b = 7.6$ ft.

$u = 1$ $r = 5.0$ ft $t = 1.55$ min

$$T = \frac{Q}{4\pi s} W(u) = \frac{33.5 \text{ gpm}}{4\pi(0.138 \text{ ft})}(1) \cdot \frac{1440 \text{ min}}{\text{day}} = 27818 \text{ gpd/ft}$$

$$K = \frac{T}{b} = \frac{27818}{7.6 \text{ ft}} \text{gpd/ft} \cdot \frac{1 \text{ ft}^3}{7.48 \text{ gal}} = 489 \text{ ft/day}$$

$$S = \frac{u\, 4Tt}{r^2} = (1)\frac{4(27818 \text{ gpd/ft})(1.55 \text{ min})}{(5 \text{ ft})^2} \cdot \frac{1 \text{ day}}{1440 \text{ min}} \cdot \frac{1 \text{ ft}^3}{7.48 \text{ gal}}$$

$$= 0.64$$

MRO FORM 1550
1 OCT 72

OMAHA DISTRICT — COMPUTATION SHEET — CORPS OF ENGINEERS

PROJECT RMA W-5 PUMP TEST	SHEET NO.	OF	
ITEM ANALYSIS OF RECOVERY DATA s' vs t/t' WELLS P-1, P-5 P-2, P-4	BY BECKER	DATE	
	CHKD. BY	DATE	

P-1;

$\Delta s'$ = drawdown over log cycle: 10–100 MIN = .41 ft $Q = 33.5$ gpm $b = 7.6$ ft

$$T = \frac{2.303Q}{4\pi\Delta s'} = \frac{2.303(33.5\,gpm)}{4\pi\,(.41ft)} \cdot 1440\frac{min}{day} = 24879\ gpd/ft$$

$$K = \frac{T}{b} = \frac{24879\,gpd/ft}{7.6ft} \cdot \frac{1ft^3}{7.48gal} = 438\ ft/day$$

P-5;

$\Delta s' = .30$ ft $Q = 33.5$ gpm $b = 8.47$ ft

$$T = \frac{2.303Q}{4\pi\Delta s'} = \frac{2.303(33.5)}{4\pi\,(.30ft)},\ 1440\frac{min}{day} = 29469\ gpd/ft$$

$$K = \frac{T}{b} = \frac{29469\,gpd/ft}{8.47ft} \cdot \frac{1ft^3}{7.48gal} = 465\ ft/day$$

P-2:

$\Delta s' = .30$ ft $Q = 33.5$ $b = 7.4$ ft

$$T = \frac{2.303Q}{4\pi\Delta s'} = \frac{2.303(33.5\,gpm)}{4\pi\,(.30ft)},\ 1440\frac{min}{day} = 29469\ gpd/ft$$

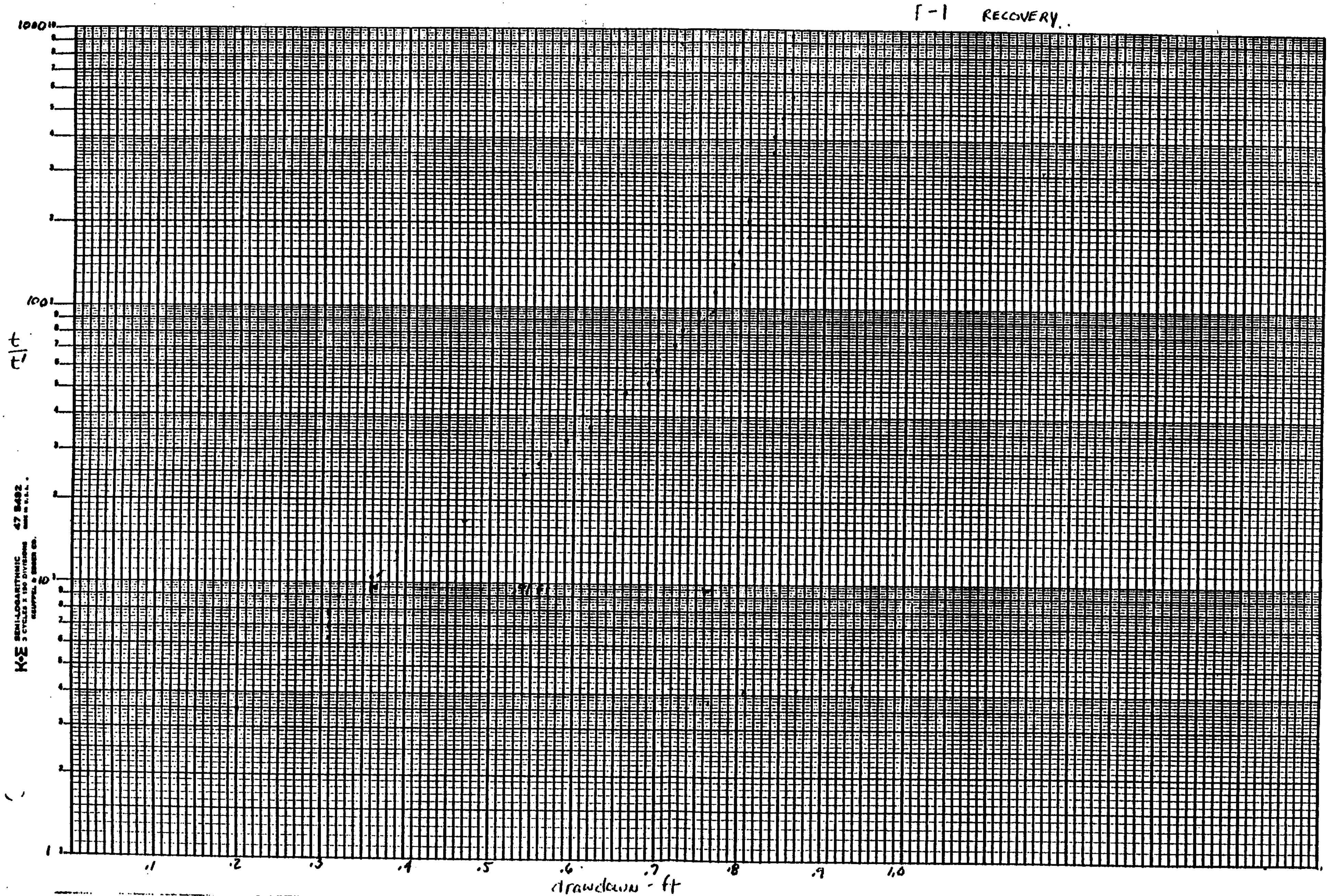
$$K = \frac{T}{b} = \frac{29469\,gpd/ft}{7.4ft} \cdot \frac{1ft^3}{7.48gal} = 532\ ft/day$$

P-4:

$\Delta s' = .31$ ft $Q = 33.5$ $b = 7.5$ ft

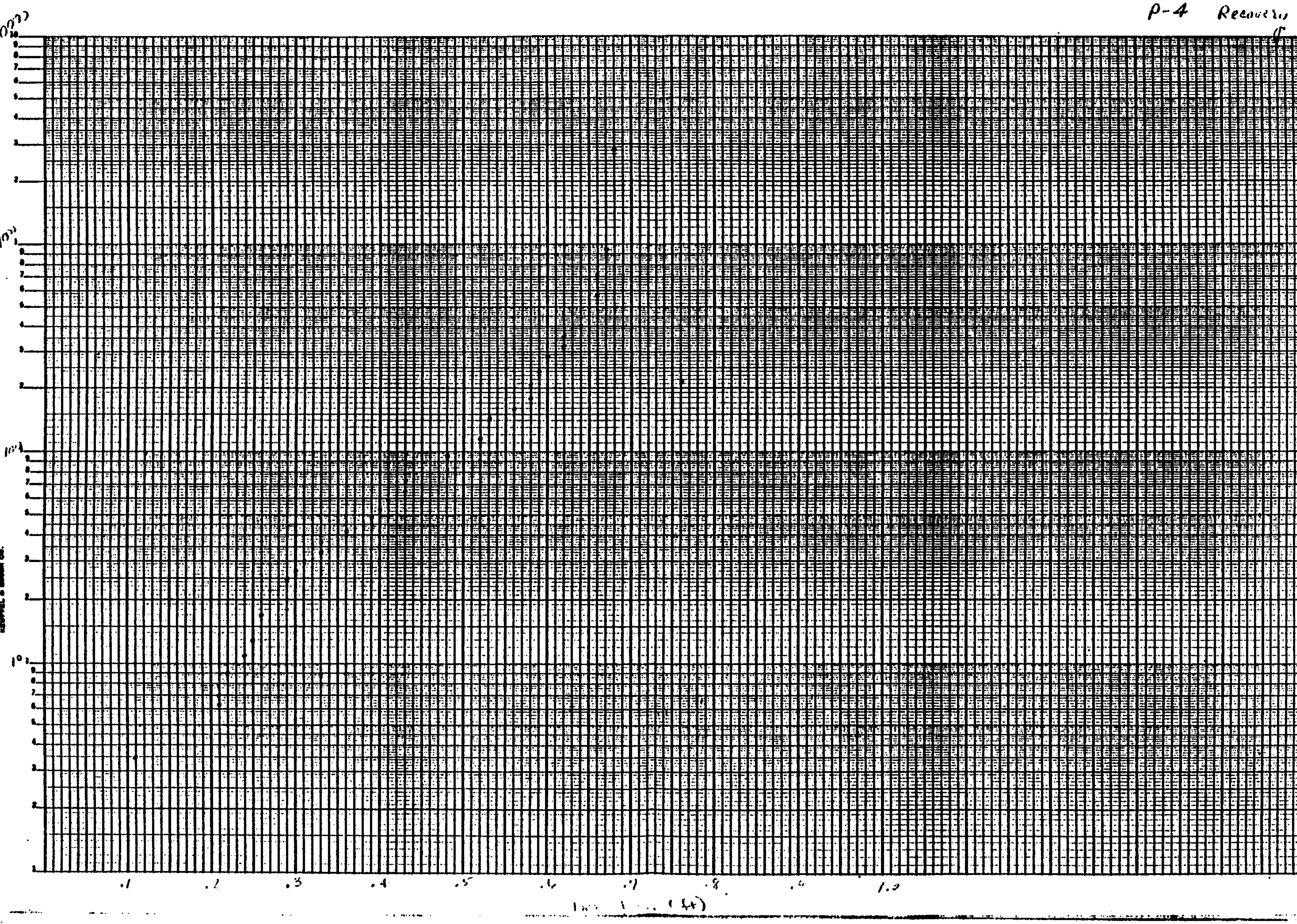
$$T = \frac{2.303Q}{4\pi\Delta s'} = \frac{2.303(33.5\,gpm)}{4\pi\,(.31ft)},\ 1440\frac{min}{day} = 28519\ gpd/ft$$

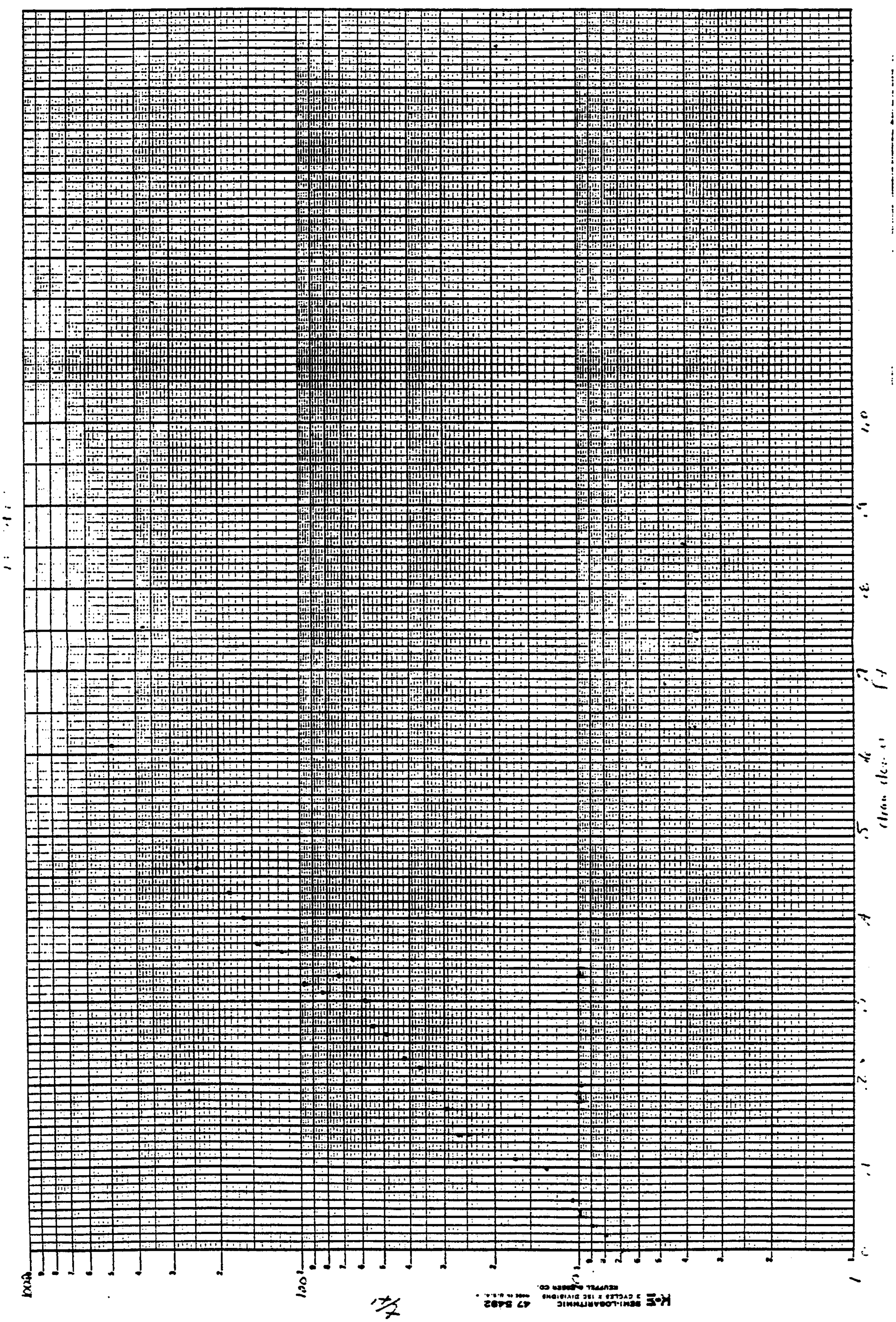
$$K = \frac{T}{b} = \frac{28519\,gpd/ft}{7.5ft} \cdot \frac{1ft^3}{7.48gal} = 508\ ft/day$$

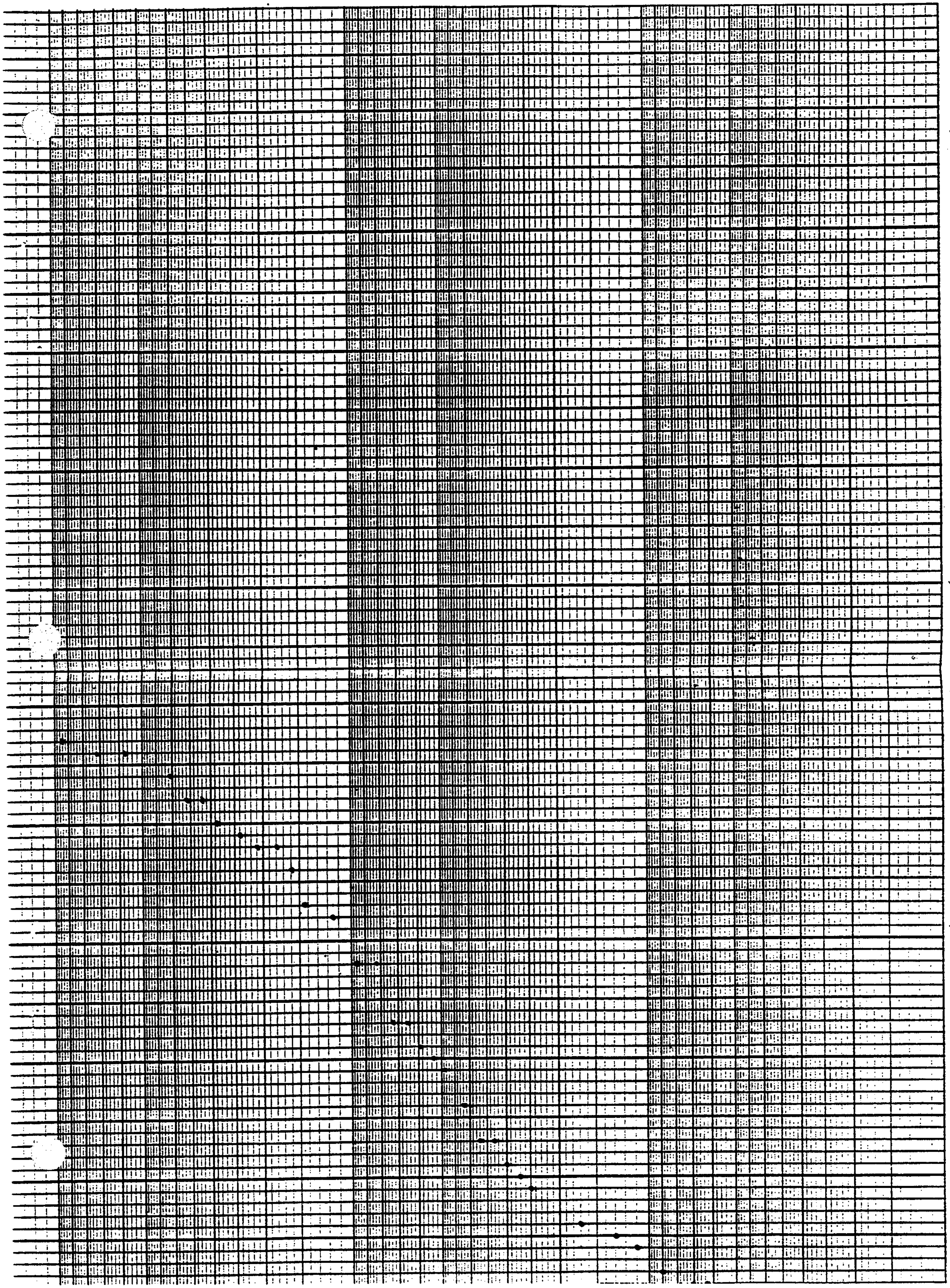


T-1 RECOVERY.
1000
100
10
1
t/t'
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
drawdown - ft
K+E SEMI-LOGARITHMIC 47 5492
3 CYCLES X 150 DIVISIONS
KEUFFEL & ESSER CO.

P-4 Recovery







SLUG TEST IN W-5A

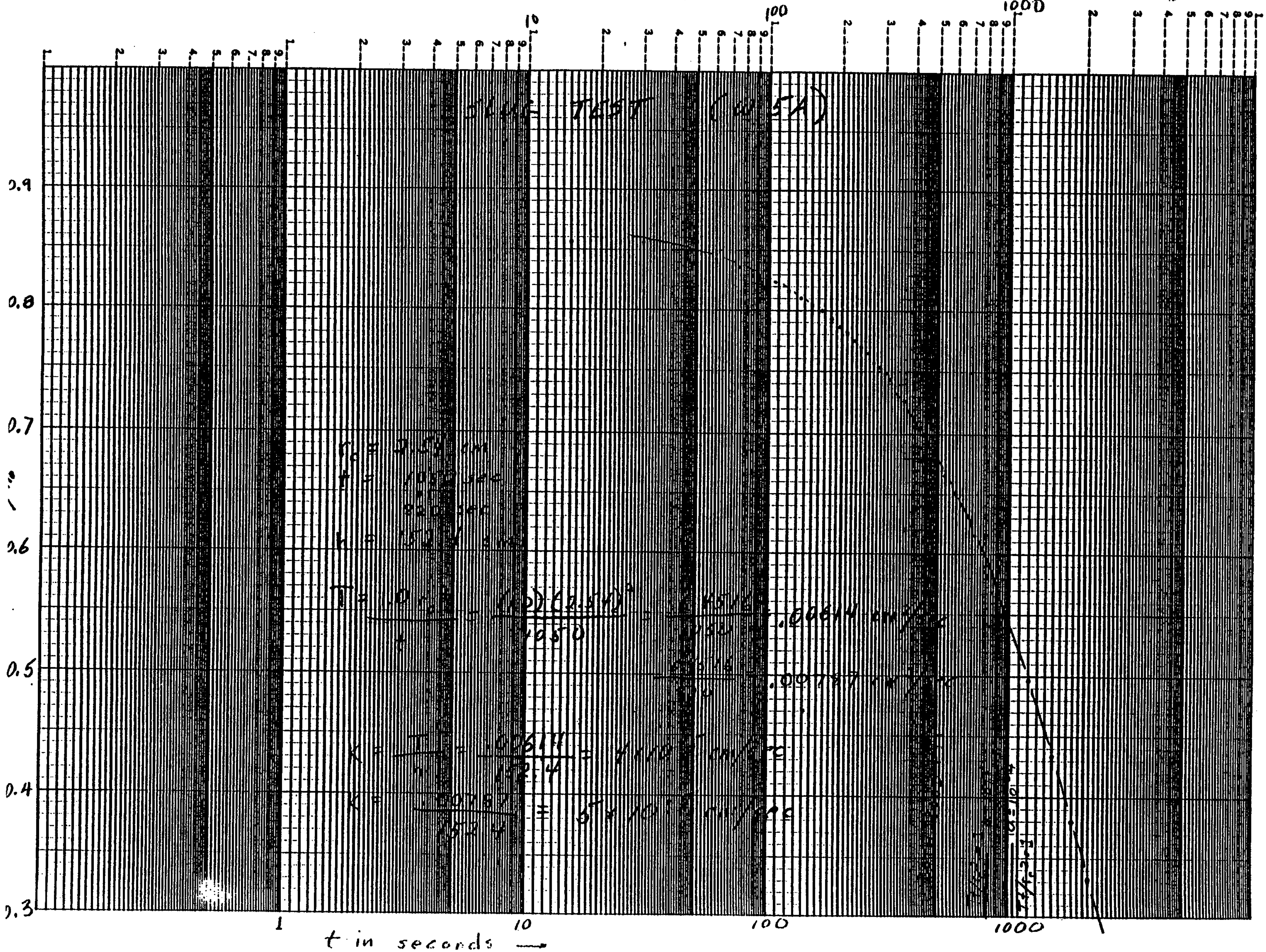
OMAHA DISTRICT | COMPUTATION SHEET | CORPS OF ENGINEERS

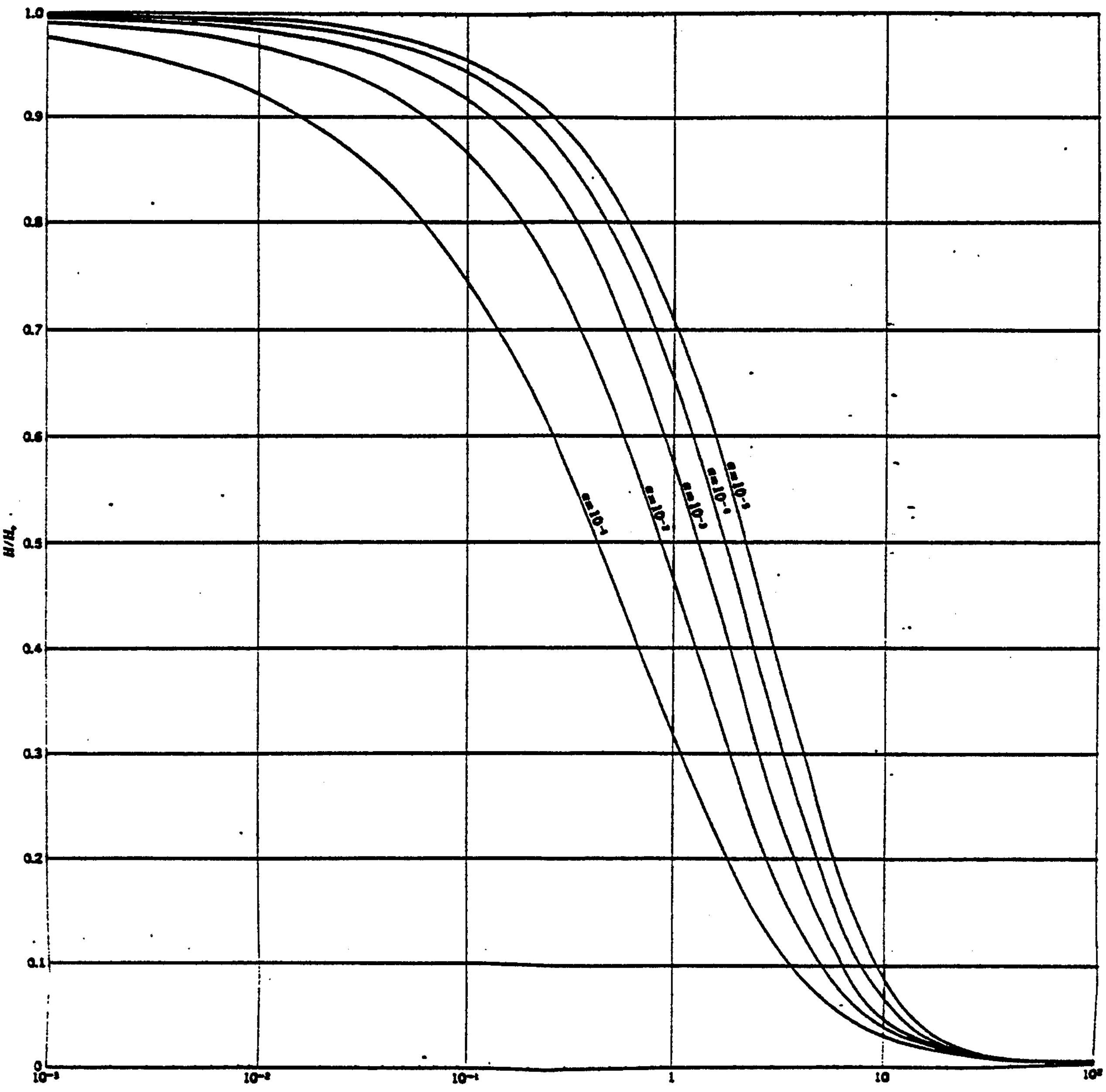
PROJECT RMA N.W. BOUNDARY	SHEET NO. 1 OF 1
ITEM SLUG TEST IN W-5A	BY / DATE
	CHKD. BY / DATE

TIME (SEC.)	H (Depth above Transducer)	H/Ho (Ho = 9.19)
0	7.83	.852
15	7.88	.857
30	7.87	.856
45	7.80	.849
60	7.75	.843
75	7.68	.837
90	7.63	.830
105	7.57	.824
120	7.52	.818
135	7.45	.811
150	7.40	.805
165	7.35	.800
180	7.29	.793
195	7.24	.788
210	7.19	.782
225	7.13	.776
240	7.08	.770
255	7.03	.765
270	6.97	.758
285	6.93	.754
300	6.88	.749
315	6.84	.744
330	6.79	.739
360	6.69	.728
420	6.49	.706
480	6.32	.688
540	6.16	.670
600	5.99	.652
720	5.67	.617
900	5.24	.570
1200	4.57	.497
1500	3.99	.434
1800	3.49	.380
2100	3.05	.332

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6213





TYPE CURVES FOR H/H_o VERSUS Tt/r_c^2 FOR FIVE VALUES OF α

After Cooper, Bredehoeft, and Papadopulos (1967, table 1)

GRAVEL FILTER PACK DESIGN

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA NW Boundary		SHEET NO. 1	OF 3
ITEM GRAVEL Pack Computations		BY RK	DATE 2/4/83
		CHKD. BY	DATE

Along Recharge line

Boring #	Sample #	DEPTH	30% Passing (in mm.)
82-50	8	36.1	.68
82-50	10	46.3	.59
82-52	7	33.5	.91
82-52	9	46.6	.44
82-54	8	35.7	.54
82-55	9	33.2	.32
82-55	16	43.0	.46
82-55	17	46.1	.80
82-56	11	38.3	.36
82-56	16	43.7	.32
82-57	10	39.0	.42
82-57	13	45.4	.75
82-58	12	40.9	.40
82-58	13	46.0	.30
82-59	11	38.8	.37
82-59	14	46.5	.28
82-60	16	48.6	.49
82-60	17	51.3	.67
82-61	6	26.3	.47

Total samples Analyzed: 19

Average for 30% Passing (in mm.): 0.504

MRO FORM 1550
1 OCT 72

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA NW Boundry	SHEET NO. 2 OF 3	
ITEM GRAVEL Pack Computations	BY RK	DATE 2/4/83
	CHKD. BY	DATE

Along Discharge line

Boring #	Sample #	DEPTH	30% Passing (in mm)
82-5	9	40.4'	0.58
82-5	10	40.9	0.55
82-5	11	45.4	0.44
82-5	12	45.7	0.43
82-6	8	36.1	0.30
82-6	9	40.3	0.80
82-6	10	40.8	1.80
82-7	11	41.6	2.40
82-7	12	45.8	1.0
82-8	7	25.7	.43
82-8	8	26.1	.33
82-8	9	30.4	0
82-8	11	41.0	.50
82-3A	11	45.5	1.6
82-3A	15	55.8	.43
82-4A	10	36.3	.41
82-4A	15	46.3	.21
82-4A	16	51.5	.38
82-5A	11	43.6	0
82-7A	13	45.9	.63
82-7A	14	48.9	.54
82-8A	4	21.3	.32
82-8A	5	26.5	.47
82-P-1	9	36.6	.58
82-P-1	14	44.1	0
82-3	10	35.4	.25
82-3	11	38.8	.20
82-3	12	40.5	.44

MRO FORM 1550
1 OCT 72

OMAHA DISTRICT — COMPUTATION SHEET — CORPS OF ENGINEERS

PROJECT RMA NW Boundary — SHEET NO. 3 OF 3

ITEM GRAVEL Pack Computations — BY RK — DATE 2/4/93

CHKD. BY — DATE

ALONG Discharge Line

Boring #	SAMPLE #	DEPTH	30% passing (in mm)
82-4	9	35.6	.41
82-4	16	36.5	.76
82-4	12	50.5	1.0

Total samples Analyzed: 31

Average for 30% Passing (in mm.): 0.587

Average for 30% Passing (in mm.) for Recharge & Discharge line: 0.555

Gravel Pack
$0.56 \times 5 = 2.8$ mm

$$C_u = \frac{D_{60}}{D_{10}} = \frac{3.2}{2.2} = 1.45$$

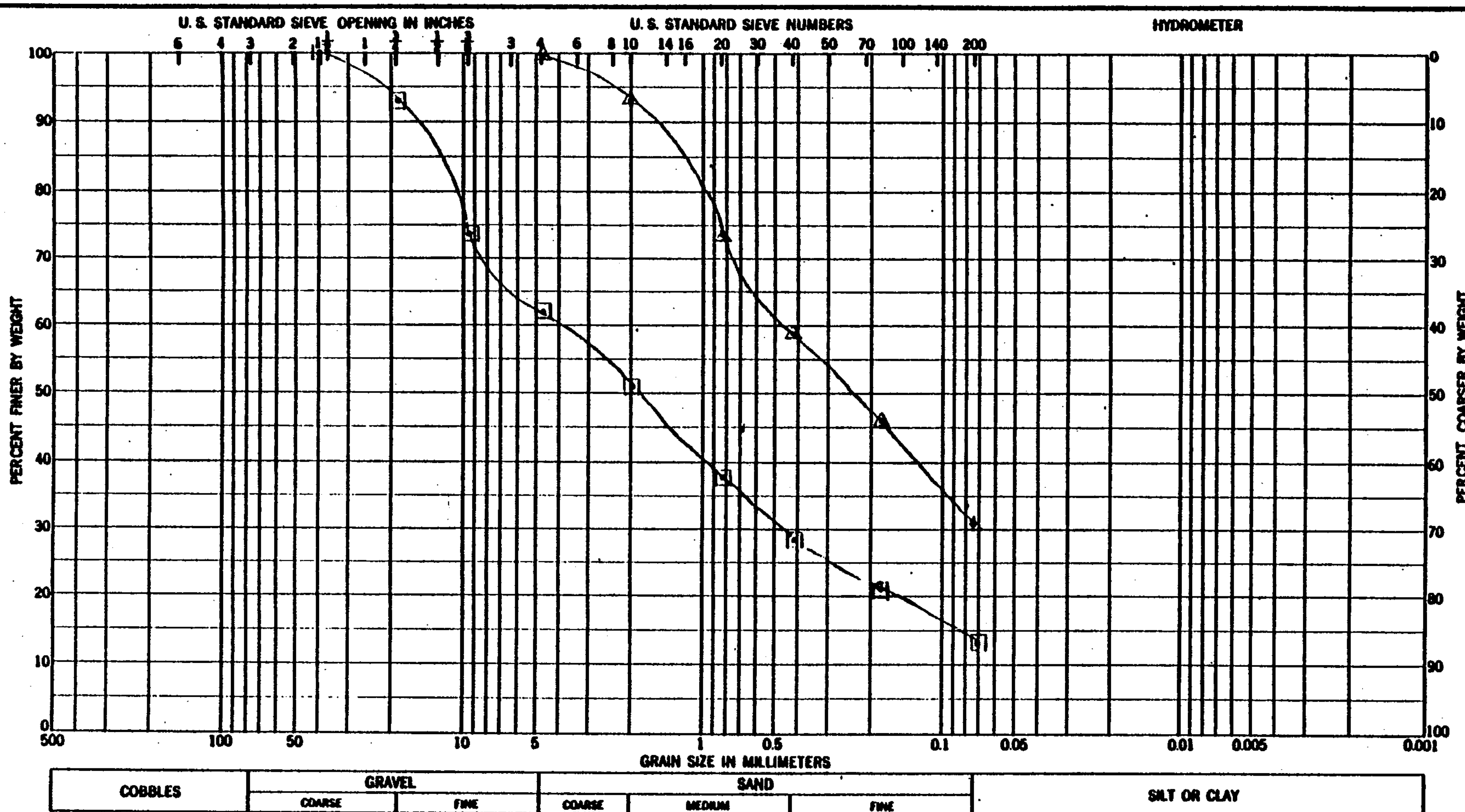
Screen slot size:

10% passing size = 2.2 mm

(2.2 mm) x (0.03937 inches) = 0.87 inches

use an 80 slot or 0.080 inches.

MRO FORM 1550
1 OCT 72



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
△ 14 82-P-1	44.1	SC				
⊡ 5 82-8A	26.5	SM				

Project RMA NW Boundary

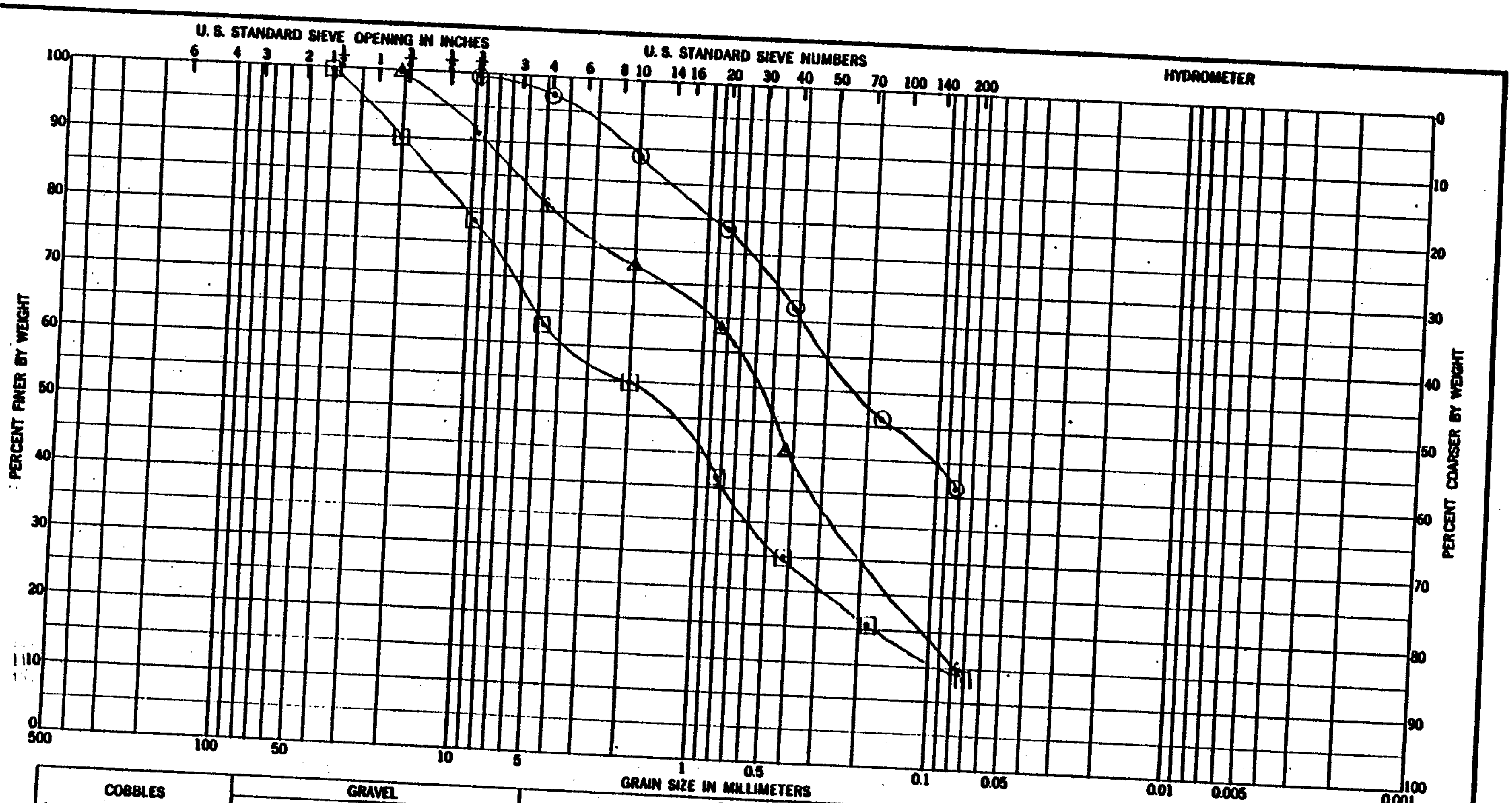
Area Discharge + Recharge

Boring No. 82-P-1, 82-8A

Date 2/4/83

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
△11 82-3	38.8	SM				
⊡9 82-4	35.6	SM				
⊙11 82-5A	43.6	SC				

Project RMA NW Boundary

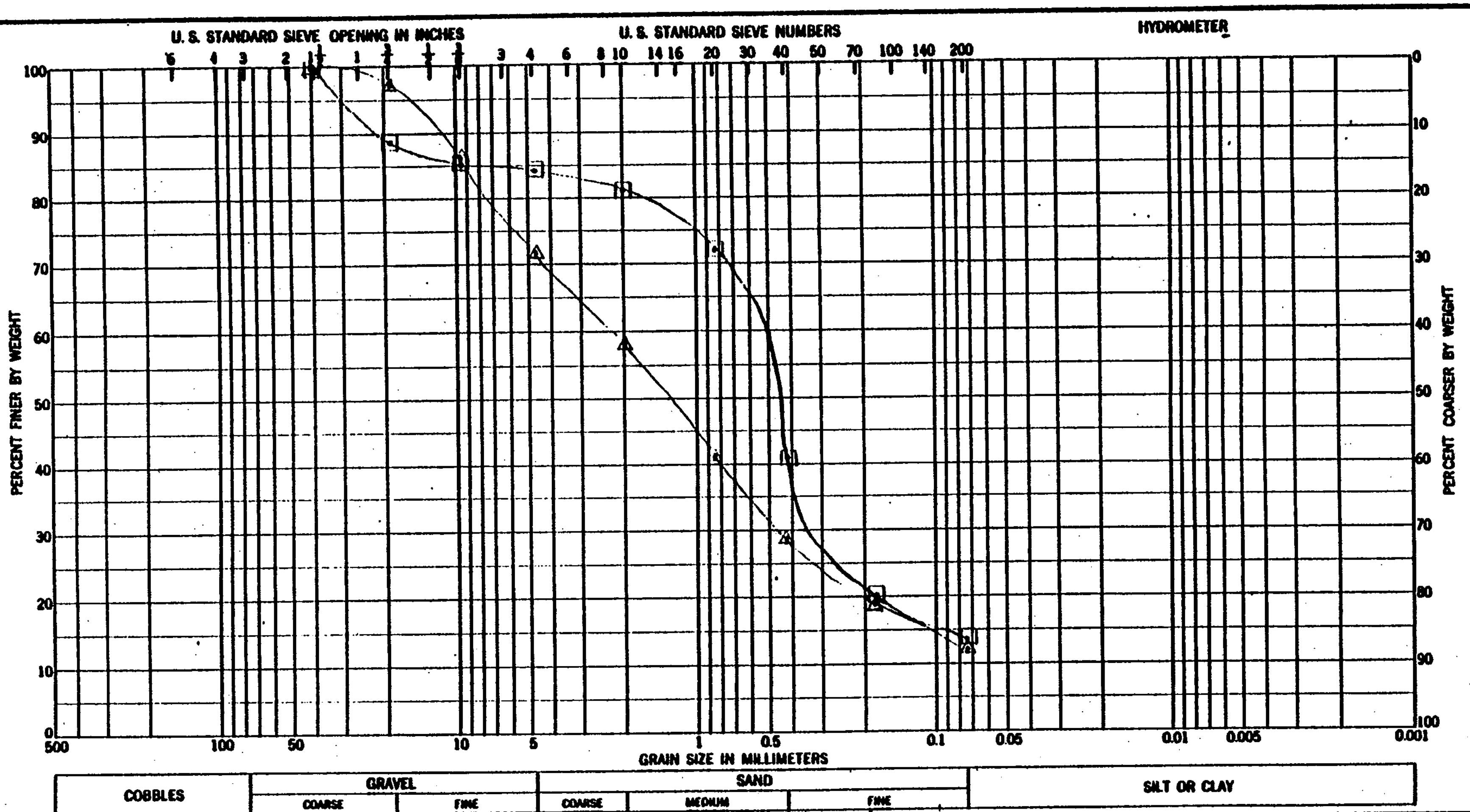
Area Discharge

Boring No. 82-3, 82-4 + 82-5A

Date 2/4/83

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
△6 82-61	56.3	SM				
⊡16 82-56	43.7	SM				

Project RMA NW Boundary

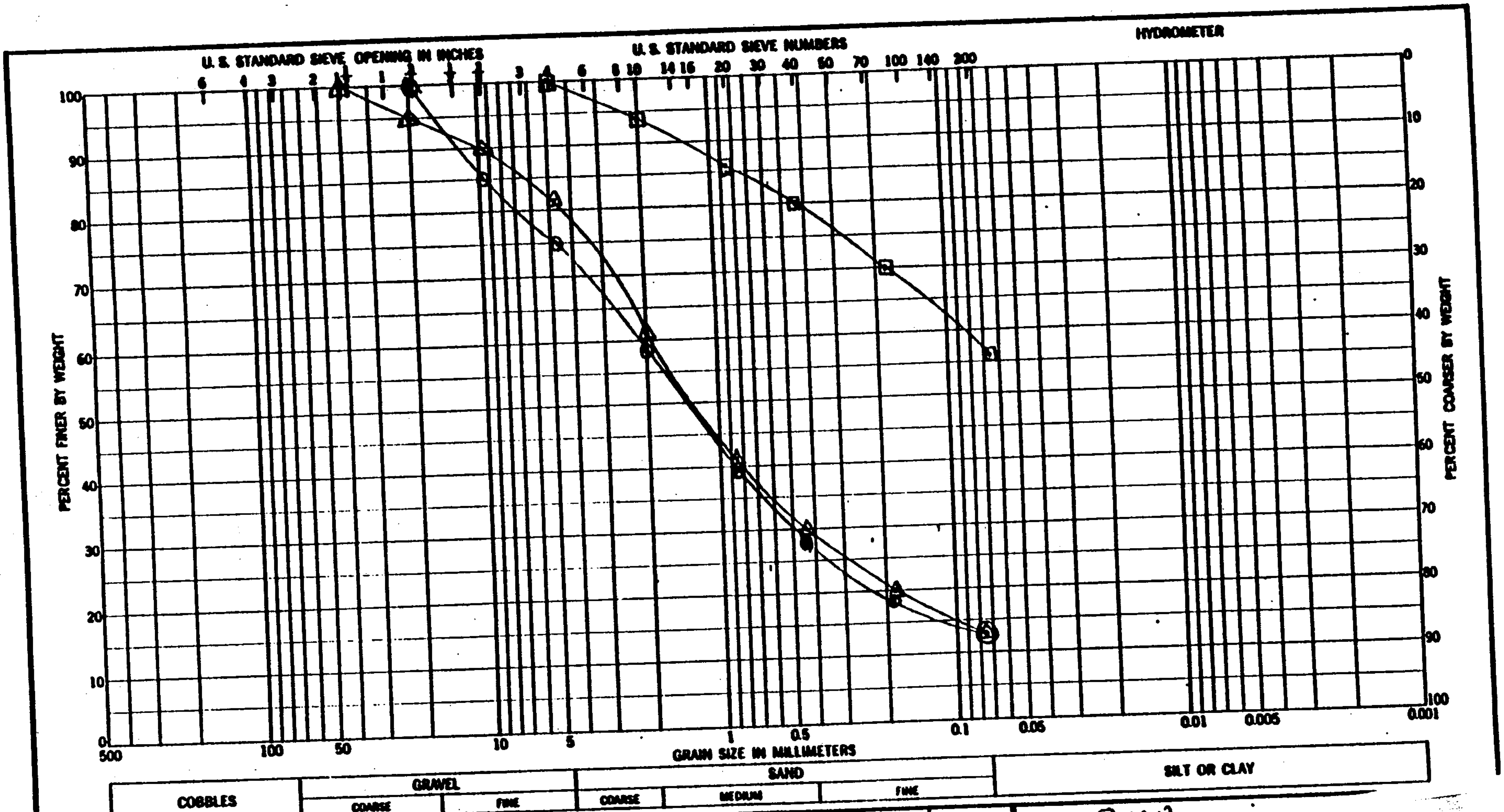
Area Recharge

Boring No. 82-61 + 82-56

Date 2/4/83

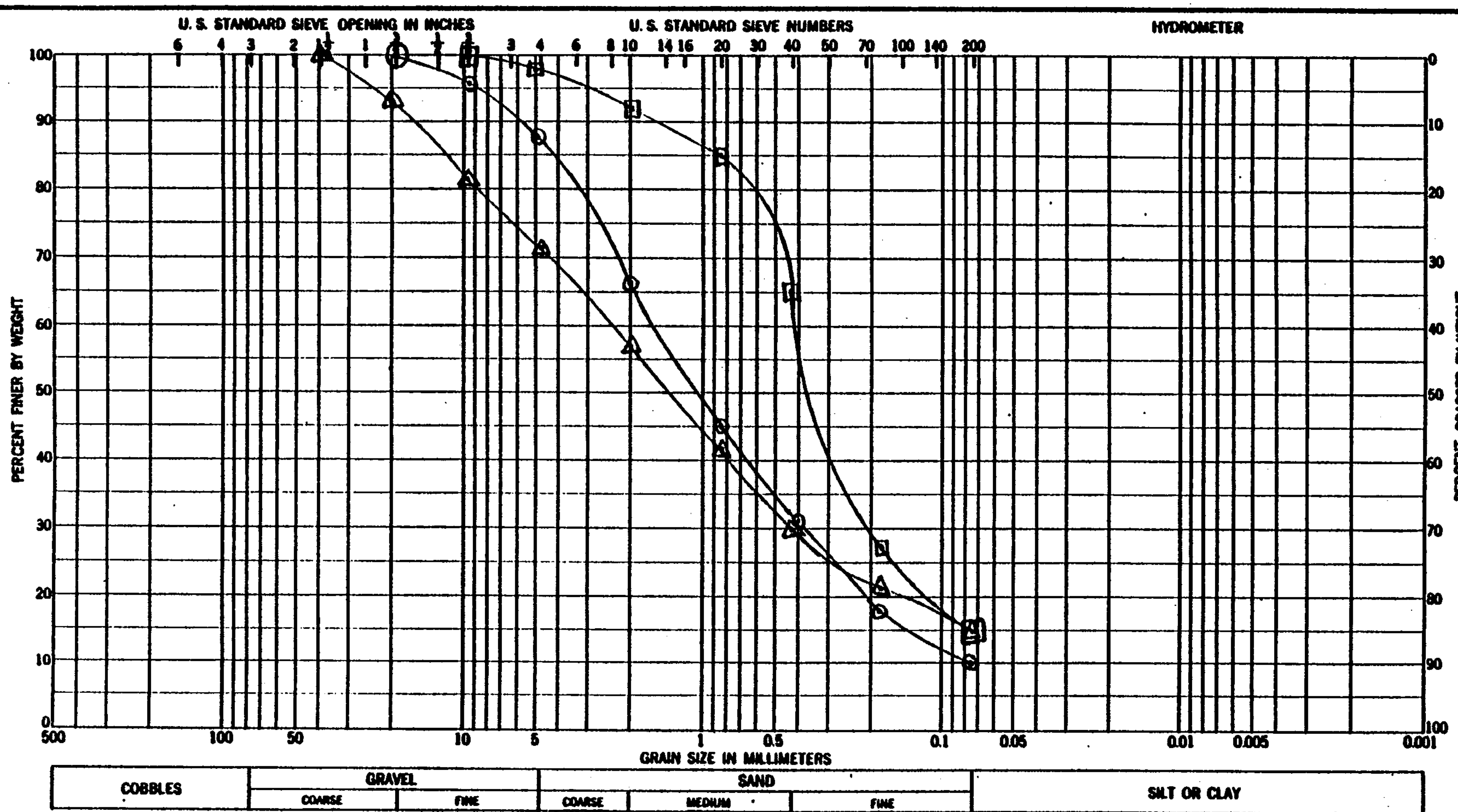
GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
△ 7	25.7	SM				
⊡ 9	30.4	CL				
⊙ 11	41.0					

Best Available Copy



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
△ 10	36.3	SM				
⊡ 15	46.3	SM				
⊙ 16	51.5	SM-SW				

GRADATION CURVES

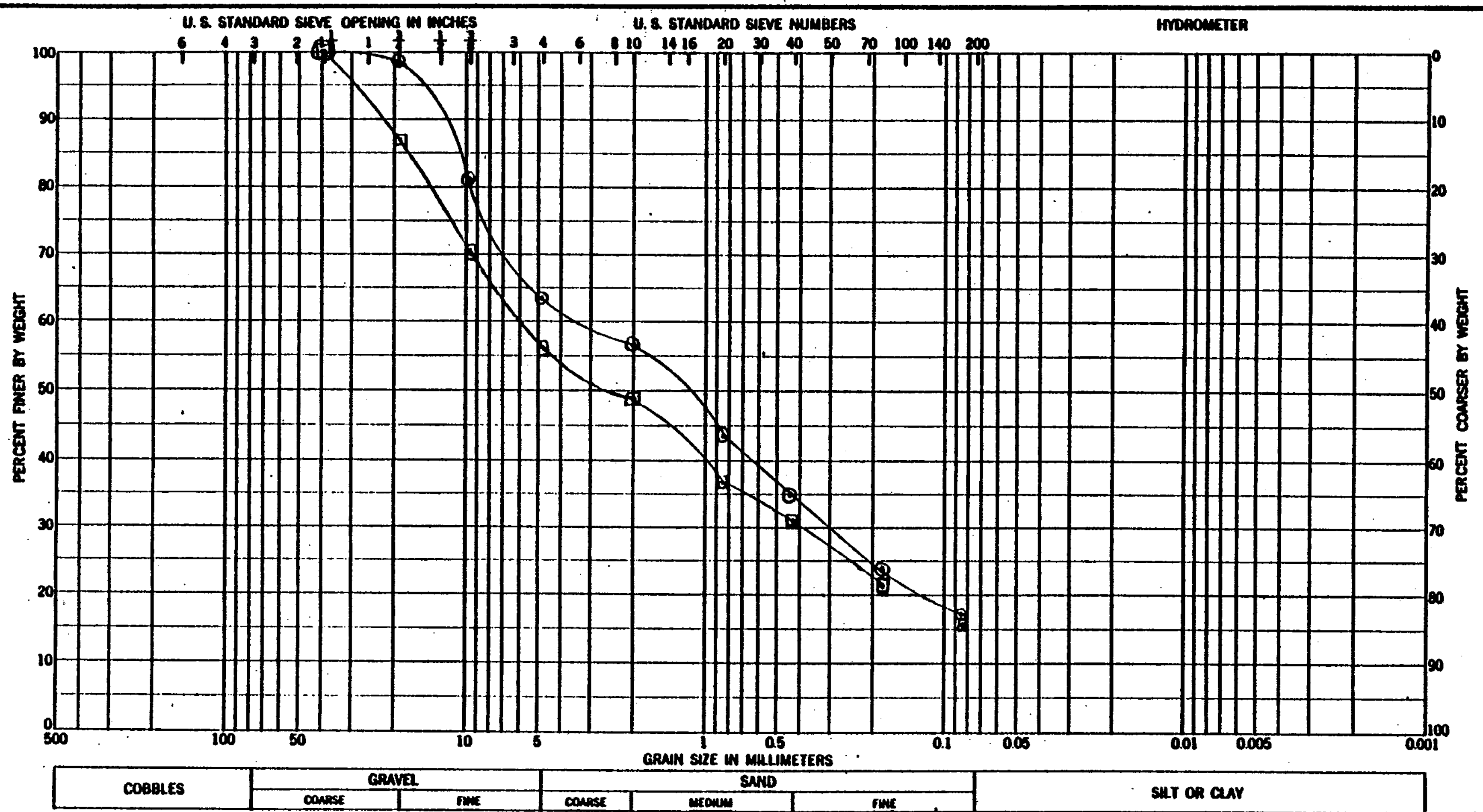
Project RMA NW Boundary

Area Discharge

Boring No. 82-4A

Date 2/4/83

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
⊡ 12	40.9	GM				
⊙ 13	46.0	SM				

Project RMA NW Boundary

Area Recharge

Boring No. 82.58

Date 2/4/83

GRADATION CURVES

ENG FORM 1 MAY 63 2087

SOIL CLASSIFICATION RECORD SHEETS

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal		Boring No: 82-1	MRD Lab. No: 82/149
Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –

Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines 005	Fines .02mm	U.S. Standard Sieve Sizes 200	Sand 80	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks	PI.
1	1.4	7.5	33	21			65	81	95	100												Sandy clay CL	Note (a)	12
2	5.6	7.0	37	21			12	26	44	62	82	100					0.78	0.20	0.05	15.6	1.0	Clayey sand SC-SW	Note (b)	16
3	10.5	9.3	NP	NP			58	66	76	83	94	100										Sandy silt ML	Note (c)	
4	10.9	–	48	31			65	81	90	95	98	100										Sandy clay CL	Note (d)	17
5	15.9	16.2	46	27			66	79	89	95	99	100										Sandy clay CL	Note (e)	19
6	16.3	–																				Sandy clay CL	Note (d)	
7	20.7	21.2	40	25			74	95	100													Sandy clay CL	Note (f)	15
8	25.5	22.7	50	32																		Fat clay CH	Note (g)	18
9	25.9	–																				Fat clay CH	Note (g)	
10	30.9	23.6	67	44																		Fat clay CH	Note (h)	23
11	31.3	–																				Fat clay CH	Note (h)	
12	35.3	–	42	25																		Lean clay CL	Note (i)	17
13	35.9	27.5	35	12			68	96	100													Sandy clay CL	Note (j)	23
14	40.2	–																				Silty gravelly sand SM-SP	Fine sand to fine gravel.	
15	41.0	–																				Silty gravelly sand SM-SP	Fine sand to fine gravel.	
16	45.7	12.7																				Silty sand SM	Fine sand.	
17	46.1	–																				Silty sand SM	Fine sand.	
18	50.2	28.2					Lost in testing.															–	–	
19	53.4	–					19	28	52	75	91	97	100									Silty sand SM	Note (k)	
20	55.5	25.6	76	54																		Shale CH	Note (l)	22
21	57.0	26.2																				Shale CH	Note (l)	

Table A-1

MRD FORM NOV. 76 16 EDITION OF MAY 70 IS OBSOLETE

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal		Boring No: 82-2	MRD Lab. No: 82/149
Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	.02mm	U.S. Standard Sieve Sizes 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
1	3.0	3.1					24	39	76	97	100											Silty sand SM	Note (m)
2	5.3	8.3	33	17			76	86	95	99	100											Sandy clay CL	Note (n) 16
3	6.5	4.0					27	48	85	99	100											Silty sand SM	Note (o)
4	10.5	10.5	38	24			70	80	94	99	100											Sandy clay CL	Note (p) 14
5	11.2	–	41	29			63	75	90	98	100											Sandy clay CL	Note (q) 12
6	15.4	4.2	27	16			33	54	88	98	100											Clayey sandstone SC	Note (r) 11
7	21.9	18.8	53	37			71	86	92	96	99	100										Sandy clay CH	Note (s) 16
8	25.9	–	46	29			77	92	97	99	100											Sandy clay CL	Note (t) 17
9	26.7	6.1					19	46	81	96	100											Silty sand SM	Note (u)
10	31.5	18.9	40	24																		Lean clay CL	Note (v) 16
11	36.1	1.3					6	12	26	36	61	82	96	100			1.9	0.58	0.15	12.7	1.2	Silty gravelly sand SM-SW	Note (w)
12	36.7	–																				Silty gravelly sand SM-SW	Note (w)
13	[illegible]	31.8																				Fat clay CH	Note (h)
14	42.4	16.6																				Silty sand SM-SP	Fine to medium sand
15	45.9	–																				Silty sand SM-SP	Fine to medium sand
16	56.1	9.6																				Silty sand SM-SW	Fine sand to fine gravel.
17	59.6	10.4																				Silty sand SM-SW	Fine sand to fine gravel.
18	60.0	–																				Silty sand SM-SW	Fine sand to fine gravel.
19	69.0	20.0	76	48																		Shale CH	Note (x) 28
20	69.7	–																				Shale CH	Note (x)

MRD FORM NOV. 75 16 EDITION OF MAY 70 IS OBSOLETE

Table A-2

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: 82-3 and 82-4	MRD Lab. No: 82/149
Station: – / Range: / Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	P.I.	Hyd. Analysis Fines 005	02mm	U.S. Standard Sieve Sizes 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks	PI.
Hole	82-3																							
1	1.4	10.4	41	23			65	78	92	98	100											Sandy clay CL	Note (a)	18
2	5.4	8.5	31	18			48	62	78	91	100											Clayey sand SC	Note (b)	13
3	6.4	–	26	8			48	75	91	98	100											Clayey sand SC	Note (c)	18
4	10.4	–	39	18			86	96	98	99	100											Lean clay CL	Note (d)	21
5	11.5	28.9	67	45																		Fat clay CH	Note (e)	22
6	16.4	13.1	40	27			44	58	80	96	100											Clayey sand SC	Note (f)	13
7	20.6	20.7																				Clayey sand SC	Note (f)	
8	25.7	21.2	38	42																		Fat clay CH	Note (g)	16
9	30.4	35.0	89	63																		Fat clay CH	Note (h)	26
10	35.4	20.9					12	17	48	70	81	89	95	100			0.54	0.25	0.030	18.0	3.9	Silty sand SM-SP	Note (i)	
11	38.8	–					16	23	47	64	73	81	91	100								Silty gravelly sand SM	Note (j)	
12	40.5	10.8					12	18	30	41	62	83	94	100			1.4	0.44	0.048	29.2	2.9	Silty gravelly sand SM-SW	Note (k)	
13	45.4	11.1																				Silty gravelly sand SM-SW	Note (k)	
14	56.3	21.1	83	52																		Shale CH	Note (l)	21
Hole	82-4																							
1	1.3	14.4	56	40																		Fat clay CH	Note (m)	16
2	5.3	11.8	37	24			62	73	86	95	100											Sandy clay CL	Note (n)	13
3	10.7	18.2	54	38			81	89	95	97	98	99	100									Fat clay CH	Note (o)	16
4	15.5	12.1	41	29			56	70	85	95	100											Sandy clay CL	Note (p)	11
5	20.6	25.2	51	30																		Fat clay CH	Note (q)	21
6	25.6	25.4	68	37																		Fat clay CH	Note (r)	31
7	30.6	29.6																				Fat clay CH	Note (o)	
8	35.3	–	52	35			79	90	93	96	99	100										Sandy clay CH	Note (s)	17
9	35.6	–					14	21	30	42	55	63	78	90	100							Silty gravelly sand SM	Note (t)	
10	36.5	7.2					8	12	21	32	48	58	73	91	100		5.4	0.76	0.11	49.1	0.97	Silty gravelly sand SM-SP	Note (u)	
11	40.6	7.5																				Sandy clay CL	Note (s)	
12	50.5	9.9					8	12	18	27	41	62	79	94	100		4.7	1.0	0.13	36.2	1.6	Silty gravelly sand SM-SW	Note (v)	
13	50.9	–																				Silty gravelly sand SM-SW	Note (v)	
14	56.1	22.5	79	49																		Shale CH	Note (w)	30

MRD FORM 16 NOV. 75 EDITION OF MAY 70 IS OBSOLETE

Table B-1

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal			Boring No: 82-5 and 82-6	MRD Lab. No: 82/149
Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Hyd. Analsis Fines .005	Hyd. Analsis Fines .02mm	Fines 200	Sand 60	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67		Remarks	PI.
Hole	82-5																								
1	1.5	6.4					45	58	77	95	100											Silty sand	SM	Note (a)	
2	5.6	8.2	38	22			59	69	84	97	100											Sandy clay	CL	Note (b)	16
3	10.4	7.2																				Sandy clay	CL	Note (b)	
4	16.0	5.0	36	24			26	36	51	67	81	93	100									Clayey sand	SC	Note (c)	12
5	20.6	14.6	40	24			54	68	85	97	100											Sandy clay	CL	Note (d)	16
6	25.5	19.3	43	26																		Lean clay	CL	Note (e)	17
7	30.8	24.9																				Lean clay	CL	Note (e)	
8	35.5	27.2	61	35																		Fat clay	CH	Note (f)	26
9	40.4	9.7					6	10	24	41	65	83	94	100			1.7	0.58	0.15	11.3	1.3	Silty gravelly sand	SM-SW	Note (g)	
10	40.9	–					9	15	26	39	63	77	94	100			1.8	0.55	0.085	21.1	2.0	Silty gravelly sand	SM-SW	Note (h)	
11	45.4	8.2					10	17	28	41	63	84	96	100			1.9	0.44	0.074	25.7	1.4	Silty gravelly sand	SM-SW	Note (i)	
12	45.7	–					12	19	29	42	63	83	97	100			1.9	0.43	0.058	32.8	1.7	Silty gravelly sand	SM-SW	Note (j)	
13	50.8	18.4	64	46																		Shale	CH	Note (k)	18
Hole	82-6																								
1	1.4	6.7	41	26			62	78	94	99	100											Sandy clay	CL	Note (l)	15
2	5.4	8.1					39	54	79	96	100											Silty sand	SM	Note (m)	
3	10.5	7.8																				Silty sand	SM	Note (m)	
4	15.6	12.6	54	31																		Fat clay	CH	Note (n)	23
5	20.4	17.1																				Fat clay	CH	Note (f)	
6	25.5	17.9	47	29			87	95	99	100												Lean clay	CL	Note (o)	18
7	30.5	16.0																				Lean clay	CL	Note (o)	
8	36.1	2.4					11	19	35	45	60	81	94	100			1.9	0.30	0.055	34.5	0.86	Silty gravelly sand	SM-SP	Note (p)	
9	40.3	7.8					4	8	19	32	48	69	83	89	100		2.3	0.80	0.20	11.5	1.4	Gravelly sand	SW	Note (q)	
10	40.8	–					3	5	9	15	33	63	74	86	100		4.4	1.8	0.50	8.8	1.5	Gravelly sand	SW	Note (r)	
11	45.5	29.0	102	78																		Shale	CH	Note (s)	24

Table C-1

MRD FORM 16 NOV. 75 EDITION OF MAY 70 IS OBSOLETE

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal

Boring No: 82-7 and 82-8

MRD Lab. No: 82/149

Station: -

Range: -

Surf. Elev: -

Depth To Water Table: -

Bottom Of Hole: -

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Hyd. Analysis Fines .005	Hyd. Analysis Fines .02mm	200	Sand 80	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks	Pl.
Hole 82-7																								
1	1.5	6.6	29	16			45	70	94	100												Clayey sand SC	Note (a)	13
2	5.4	7.3	34	17																		Lean clay CL	Note (b)	17
3	10.4	13.3	54	35			62	75	91	96	98	100										Sandy clay CH	Note (c)	19
4	15.8	10.1	35	24			55	72	92	98	100											Sandy clay CL	Note (d)	11
5	20.7	13.9	56	40			74	84	91	96	99	100										Sandy clay CH	Note (e)	16
6	25.6	17.5	39	23																		Lean clay CL	Note (f)	16
7	30.5	22.1	63	44																		Fat clay CH	Note (g)	13
8	35.6	23.4	55	38																		Fat clay CH	Note (h)	17
9	40.6	25.0					37	84	100													Silty sand SM	Note (i)	
10	41.0	-																				Silty sand SM	Note (i)	
11	41.6	-					9	13	18	22	29	35	42	62	100		18.0	2.4	0.090	200.0	3.6	Silty sandy gravel GM-GP	Note (j)	
12	45.8	5.4					8	12	18	27	44	59	63	66	100		6.2	1.0	0.15	41.3	1.1	Silty gravelly sand SM-SW	Note (k)	
13	51.0	25.8	80	56																		Shale CH	Note (l)	24
14	51.5	-																				Shale CH	Note (l)	
Hole 82-8																								
1	1.5	11.6	44	27																		Lean clay CL	Note (m)	17
2	5.4	13.5	47	29			56	72	90	97	99	100										Sandy clay CL	Note (n)	18
3	10.6	16.1	46	24			80	84	94	98	100											Sandy clay CL	Note (o)	22
4	15.7	17.3																				Sandy clay CL	Note (o)	
5	20.9	14.9	43	28																		Lean clay CL	Note (p)	15
6	25.3	-	28	11			30	41	56	67	80	90	96	100								Clayey sand SC	Note (q)	17
7	25.7	4.0					13	20	30	41	61	82	90	95	100							Silty gravelly sand SM	Note (r)	
8	26.1	-					12	19	34	54	83	96	99	100			0.99	0.33	0.043	23.0	2.6	Silty sand SM-SW	Note (s)	
9	30.4	12.0	39	21			56	70	80	86	94	100										Sandy clay CL	Note (t)	18
10	35.6	12.7																				Sandy clay CL	Note (t)	
11	41.0	7.1					13	19	28	40	59	75	85	100								Silty gravelly sand SM	Note (u)	
12	45.6	24.0	78	55																		Shale CH	Note (v)	23
13	46.2	-																				Shale CH	Note (v)	

MRD FORM 16 NOV. 75 EDITION OF MAY 70 IS OBSOLETE

Table D-1

SOIL CLASSIFICATION RECORD SHEET

Sheet 1 of 3

Project: Rocky Mountain Arsenal		Boring No: 82-3A through 82-5A, 82-7A, 82-8A, 82-P-1	MRD Lab. No: 83/75
Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	.02mm	U.S. Standard Sieve Sizes 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
Hole	82-3A																						
1	1.4																					Lean clay CL	
2	6.2																					Silty sand SM	
3	11.0																					Sandy clay CL	
4	16.4																					Lean clay CL	
5	21.0																					Sandy clay CL	
6	26.0																					Lean clay CL	
7	31.0																					Lean clay CL	
8	36.0																					Lean clay CL	
9	38.5																					Lean clay CL	
10	40.3																					Sand SP	
11	45.5						1	2	4	11	40	95	100				2.8	1.6	0.77	3.6	1.2	Sand SP	
12	51.5																					Gravelly sand SP	
13	53.0																					Fat clay CH	
14	53.9																					Sand SP	
15	55.8						12	19	29	40	52	67	81	96	100		3.0	0.43	0.052	57.7	1.2	Silty gravelly sand SM-SW	
16	61.4																					Shale CH	
Hole	82-4A																						
1	1.3																					Sandy clay CL	
2	1.5																					Sandy clay CL	
3	6.5																					Sandy clay CL	
4	7.0																					Lean clay CL	
5	11.5																					Lean clay CL	
6	16.7																					Sandy clay CL	
7	20.4																					Fat clay CH	
8	26.8																					Fat clay CH	
9	32.0																					Lean clay CL	
10	36.3						15	21	30	42	57	72	82	94	100							Silty gravelly sand SM	
11	38.9																					Silty gravelly sand SM	
12	41.2																					Silty sand SM-SP	
13	43.2																					Silty sand SM-SP	
14	43.8																					Silty sand SM-SP	
15	46.3						15	37	65	85	93	98	100									Silty sand SM	

MRD FORM NOV. 75 16 EDITION OF MAY 70 IS OBSOLETE

Table A-1

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: 82-3A through 82-5A, 82-7A, 82-8A, and 82-P-1	MRD Lab. No: 83/75
Station: - / Range: - / Surf. Elev: -	Depth To Water Table:	Bottom Of Hole: -

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	.02mm	U.S. Standard Sieve Sizes 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
Hole	82-4A Continued																						
16	51.5						10	18	31	45	66	88	96	100								Silty sand SM-SW	
17	52.9																					Silty sand SM-SW	
18	54.0																					Shale CH	
19	56.0																					Shale CH	
Hole	82-5A																						
1	1.4																					Claydy sand SC	
2	6.3						31	43	64	90	100											Clayey sand SC	
3	10.9																					Sandy clay CL	
4	16.0																					Sandy clay CL	
5	21.0																					Lean clay CL	
6	26.0																					Lean clay CL	
7	31.0																					Lean clay CL	
8	36.0																					Fat clay CH	
9	38.6																					Sandy clay CL	
10	41.9																					Lean clay CL	
11	43.6						42	52	67	79	89	97	100									Clayey sand SC	
12	45.5																					Silty sand SM	
13	49.3																					Shale CH	
Hole	82-7A																						
1	1.4																					Lean clay CL	
2	5.9																					Lean clay CL	
3	11.3																					Lean clay CL	
4	16.2																					Sandy clay CL	
5	21.6																					Lean clay CL	
6	26.2																					Sandy clay CL	
7	31.0																					Sandy clay CL	
8	31.6																					Silty sand SM	
9	35.9																					Lean clay CL	
10	38.4																					Lean clay CL	
11	40.8																					Sandy clay CL	
12	41.7																					Silty Gravelly sand SM-SP	

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal		Boring No: 82-3A through 82-5A, 82-7A, 82-8A, and 82-P-1	MRD Lab. No: 83/75
Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines 005	02mm	U.S. Standard Sieve Sizes 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
Hole	82-7A continued																						
13	45.9						4	8	22	36	52	69	82	91	100		2.8	0.63	0.19	14.7	0.75	Gravelly sand SP	
14	48.9						9	14	24	38	53	64	72	77	100		3.3	0.54	0.088	37.5	1.0	Silty gravelly sand SM-SW	
15	50.3																					Silty sand SM	
16	51.1																					Shale CH	
17	55.8																					Shale CH	
Hole	82-8A																						
1	5.9																					Lean clay CL	
2	10.3																					Sandy clay CL	
3	16.4																					Silty gravelly sand SM-SP	
4	21.3						10	17	33	50	70	85	92	95	100		1.2	0.32	0.088	15.0	1.1	Silty gravelly sand SM-SW	
5	26.5						14	21	29	38	51	62	74	93	100							Silty gravelly sand SM	
6	31.4																					Lean clay CL	
7	35.9																					Shale CH	
8	40.8																					Shale CH	
Hole	82-P-1																						
1	1.5																					Lean clay CL	
2	5.9																					Sandy clay CL	
3	10.9																					Sandy clay CL	
4	16.2																					Sandy clay CL	
5	21.3																					Sandy clay CL	
6	26.4																					Fat clay CH	
7	31.1																					Lean clay CL	
8	35.5																					Silty sand SM	
9	36.6						10	17	27	36	46	60	72	90	100		5.0	0.58	0.073	68.5	0.92	Silty gravelly sand SM-SP	
10	38.4																					Gravelly sand SW	
11	40.5																					Silty sand SM-SP	
12	41.4																					Gravelly sand SW	
13	43.1																					Clayey sand SC	
14	44.1						31	46	59	74	94	100										Clayey sand SC	
15	46.2																					Clayey sand SC	

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Table A-1

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal		Boring No: 82-9	MRD Lab. No: 82/149
Station: -	Range: -	Surf. Elev: -	Depth To Water Table: -	Bottom Of Hole: -

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	Fines .02mm	U.S. Standard Sieve Sizes 200	Sand 80	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67		Remarks	Pl.
1	1.4	7.8																				Lean clay	CL	Note (b)	
2	5.8	8.5	34	19			53	67	83	92	96	100										Sandy clay	CL	Note (w)	15
3	10.7	6.5																				Sandy clay	CH	Note (e)	
4	15.4	-																				Clayey sand	SC	Note (g)	
5	15.9	2.2					11	17	29	41	62	82	90	100			1.9	0.43	0.063	30.2	1.5	Silty gravelly sand	SM-SW	Note (x)	
6	20.7	-					9	14	22	33	55	78	89	98	100		2.3	0.70	0.10	23.0	2.1	Silty gravelly sand	SM-SW	Note (y)	
7	21.0	1.6					7	11	17	23	32	48	63	100			16.8	1.8	0.15	112.0	1.3	Silty sandy gravel	GM-GW	Note (e)	
8	25.7	1.6					5	13	65	94	99	100					0.41	0.26	0.13	3.2	2.0	Sand	SP	Note (aa)	
9	26.3	-					8	12	23	40	59	71	84	100			2.0	0.58	0.13	15.4	1.3	Silty gravelly sand	SM-SW	Note (bb)	
10	30.4	-					4	7	15	32	63	89	98	100			1.9	0.8	0.25	7.6	1.3	Sand	SW	Note (cc)	
11	31.2	7.5					9	15	26	32	40	53	68	91	100		6.8	0.61	0.084	81.0	0.65	Silty sandy gravel	GM-GW	Note (dd)	
12	31.6	-					Lost in testing															Clayey sand	SC	Note (ee)	
13	35.3	-	40	27			16	22	32	44	65	87	98	100								Clayey sand	SC	Note (ee)	13
14	35.5	-	73	54																		Shale	CH	Note (ff)	19
15	36.1	29.0	87	59																		Shale	CH	Note (gg)	28

MRD FORM 16
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Table D-2

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: 82-10 and 82-11	MRD Lab. No: 82/149
Station: – / Range: – / Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	02mm	U.S. Standard Sieve Sizes 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks	PL
Hole 82-10																								
1	1.5	8.7	29	18			57	75	92	100												Sandy clay CL	Note (a)	11
2	6.0	7.3	NP	NP			55	82	99	100												Sandy silt ML	Note (b)	
3	10.7	11.4	35	21			62	75	88	95	98	100										Sandy clay CL	Note (c)	14
4	15.6	9.5																				Sandy clay CL	Note (c)	
5	20.9	17.1	28	18																		Lean clay CL	Note (d)	10
6	25.5	–					10	16	28	40	59	82	92	98	100		2.1	0.43	0.078	26.9	1.1	Silty gravelly sand SM-SW	Note (e)	
7	26.2	0.9					7	13	24	35	53	75	86	95	100		2.6	0.60	0.13	20.0	1.1	Silty gravelly sand SM-SW	Note (e)	
8	30.9	1.6					11	17	28	40	59	82	95	97	100		2.1	0.43	0.068	30.9	1.3	Silty gravelly sand SM-SW	Note (e)	
9	35.6	1.5					8	14	23	35	53	72	84	98	100		2.7	0.65	0.092	29.3	1.7	Silty gravelly sand SM-SW	Note (e)	
10	36.2	–					5	8	14	20	32	42	48	57	100		20.0	1.9	0.20	100.0	0.90	Sandy gravel GP	Note (f)	
11	41.3	29.5																				Shale CH	Note (g)	
12	41.8	–																				Shale CH	Note (g)	
Hole 82-11																								
1	1.6	11.1	48	32			84	92	98	100												Lean clay CL	Note (h)	16
2	5.5	4.1					47	70	95	100												Silty sand SM	Note (i)	
3	10.6	4.5																				Silty sand SM	Note (i)	
4	15.5	14.3	50	33			60	71	88	98	100											Sandy clay CH	Note (j)	17
5	16.3	–	48	25																		Lean clay CL	Note (k)	23
6	20.4	–																				Clayey sand SC	Note (l)	
7	21.0	14.9	51	35			75	83	92	97	99	100										Sandy clay CH	Note (m)	16
8	26.4	17.0																				Sandy clay CH	Note (m)	
9	30.7	0.8					8	14	27	39	60	84	95	100			2.1	0.50	0.10	21.0	1.2	Silty gravelly sand SM-SW	Note (n)	
10	31.3	–					6	10	19	30	47	73	80	92	100		2.8	0.90	0.15	18.7	1.9	Silty gravelly sand SM-SW	Note (o)	
11	35.6	–					11	16	27	38	60	80	89	97	100		2.0	0.43	0.068	29.4	1.4	Silty gravelly sand SM-SW	Note (o)	
12	36.2	20.4	35	21			40	65	88	95	99	100										Clayey sand SC	Note (p)	14
13	40.4	–					8	14	32	49	78	94	100				1.2	0.40	0.10	12.0	1.3	Silty sand SM-SW	Note (q)	
14	40.7	–					26	60	98	100												Silty sand SM	Note (r)	
15	41.3	16.9					11	25	72	86	97	100					0.32	0.19	0.071	4.5	1.6	Silty sand SM-SP	Note (s)	
16	45.8	37.3	70	34			57	82	96	100												Sandy silt MH	Note (t)	36
17	50.8	27.4																				Shale CH	Note (u)	

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Table E-1

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: 82-12	MRD Lab. No: 82/149
Station: – / Range: – / Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: ––

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines 005	02mm	U.S. Standard Sieve Sizes 200	Sand 60	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67		Remarks	PI.
1	1.4	6.6		*			54	71	88	96	100											Sandy clay	CL	Note (a)	
2	5.4	15.8																				Sandy clay	CH	Note (b)	
3	10.6	17.8	44	29			77	89	96	99	100											Sandy clay	CL	Note (c)	15
4	15.7	14.3																				Sandy clay	CL	Note (c)	
5	20.5	19.0																				Sandy clay	CL	Note (d)	
6	25.4	17.2	37	24			64	87	96	98	100											Sandy clay	CL	Note (e)	13
7	30.4	21.4																				Sandy clay	CH	Note (d)	
8	35.4	–	49	32																		Lean clay	CL	Note (f)	17
9	36.5	16.2					25	52	82	88	92	96	99	100								Silty sand	SM	Note (g)	
10	40.1	–																				Gravelly sand	SP	Note (h)	
11	45.5	–					14	21	31	44	66	92	99	100								Silty sand	SM	Note (i)	
12	45.8	13.5																				Silty sand	SM	Note (i)	
13	50.4	–					8	13	24	33	54	80	90	100			2.4	0.68	0.11	21.8	1.8	Silty gravelly sand	SM-SW	Note (j)	
14	50.7	11.9																				Silty sand	SM	Note (g)	
15	55.3	–					13	24	49	66	82	96	100									Silty sand	SM	Note (k)	
16	55.9	–																				Silty sand	SM	Note (l)	
17	60.3	14.8					8	13	26	48	80	96	100				1.1	0.44	0.11	10.0	1.6	Silty sand	SM-SW	Note (m)	
18	60.7	10.7																				Silty sand	SM-SW	Note (m)	
19	65.2	–	74	56																		Fat clay	CH	Note (n)	18
20	65.6	17.8																				Shale	CH	Note (o)	

* Too small for Atterberg limit test.

MRD FORM 16
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Table J-1

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal			Boring No: 12A	MRD Lab. No: 82/149
Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits)		Grading (Cumulative Percents Finer)												Gradation Curve Analysis					Classification	Remarks	
					Hyd. Analsis		U. S. Standard Sieve Sizes																	
					Fines			Sand					Gravel											
			L. L.	P. I.	.005	.02mm	200	80	40	20	10	4	3/8	3/4	1 1/2	3 in	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Tech. MEMO 3-357, May 67		PI.
1	1.4	10.3																				Sandy clay CL	Note (p)	
2	5.4	6.0	31	21																		Sandy clay CL	Note (q)	10
3	10.4	13.3																				Sandy clay CL	Note (r)	
4	15.8	16.9	48	33																		Lean clay CL	Note (s)	15
5	20.3	–																				Silty sand SM	Note (t)	
6	20.7	16.1	33	21																		Lean clay CL	Note (u)	12
7	25.5	24.5																				Lean clay CL	Note (u)	
8	30.8	26.9	63	38																		Fat clay CH	Note (v)	25
9	35.9	28.8																				Sandy clay CL	Note (w)	
10	36.5	–																				Silty sand SM	Note (g)	
11	40.5	14.9					6	12	24	36	59	85	96	100			2.1	0.61	0.12	17.5	1.5	Silty gravelly sand SM-SW	Note (x)	
12	45.5	12.2																				Silty gravelly sand SM-SW	Note (x)	
13	45.7	–					18	29	70	91	98	100										Silty sand SM	Note (y)	
14	55.3	13.0					12	19	30	39	56	86	96	100			2.4	0.44	0.050	48.0	1.6	Silty sand SM-SW	Note (z)	
15	55.8	–																				Silty sand SM	Note (i)	
16	60.5	10.5																				Silty sand SM	Note (i)	
17	61.2	–																				Silty sand SM	Note (i)	
18	66.0	26.1																				Shale CH	Note (o)	

Table J-2

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal		Boring No: 82-12B	MRD Lab. No: 82/149
Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –
Bottom Of Hole: –			

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	P.I.	Grading (Cumulative Percents Finer) Hyd. Analsis Fines 005	02mm	U.S. Standard Sieve Sizes 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks	PL
1	1.4	10.5	38	19																		Lean clay CL	Note (a)	19
2	6.1	6.4																				Clayey sand SC	Note (b)	
3	10.9	18.5	54	38																		Fat clay CH	Note (c)	16
4	15.7	18.4																				Lean clay CL	Note (d)	
5	20.4	–																				Silty sand SM	Note (e)	
6	20.8	18.4	42	28																		Lean clay CL	Note (f)	14
7	25.7	20.8	56	32																		Fat clay CH	NOte (g)	24
8	30.7	25.1																				Fat clay CH	Note (g)	
9	35.7	28.7																				Fat clay CH	Note (g)	
10	40.3	–					7	11	18	27	51	88	96	100			2.4	1.0	0.16	15.0	2.6	Silty sand SM-SW	Note (h)	
11	40.7	6.8					11	18	26	35	52	78	89	98	100		2.5	0.58	0.068	36.8	2.0	Silty gravelly sand SM-SW	Note (i)	
12	45.6	10.6					Broken jar															–	–	
13	50.7	11.7					10	15	25	36	58	82	89	100			2.2	0.55	0.074	29.7	1.9	Silty gravelly sand SM-SW	Note (j)	
14	55.5	6.4																				Clayey sand SC	Note (k)	
15	60.4	11.4																				Silty gravelly sand SM-SW	Note (i)	
16	60.9	–					14	24	38	49	63	81	89	98	100							Silty gravelly sand SM	Note (l)	
17	65.2	–	67	42																		Fat clay CH	Note (m)	25
18	65.5	19.0																				Shale CH	Note (n)	

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Table K-1

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: 82-12C	MRD Lab. No: 82/149
Station: - / Range: - / Surf. Elev: -	Depth To Water Table: -	Bottom Of Hole: -

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Hyd. Analsis Fines 005	Hyd. Analsis Fines 02mm	Fines 200	Sand 80	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks	Pl.
1	2.0	10.5																				Lean clay CL	Note (v)	
2	4.0	6.5	31	17																		Lean clay CL	Note (w)	14
3	6.0	5.2					35	67	92	97	99	100										Silty sand SM	Note (x)	
4	12.0	14.2	51	34			76	85	93	97	99	100										Sandy clay CH	Note (y)	17
5	14.0	18.3																				Sandy clay CH	Note (y)	
6	20.0	7.5					42	67	85	94	100											Silty sand SM	Note (z)	
7	22.0	18.6																				Fat clay CH	Note (aa)	
8	26.0	18.6																				Fat clay CH	Note (aa)	
9	28.0	4.4					15	24	47	58	74	94	100									Silty sand SM	Note (bb)	
10	32.0	23.7																				Sandy clay CH	Note (y)	
11	37.3	27.1																				Sandy clay CH	Note (y)	
12	37.3	20.1	45	27			50	63	80	85	91	99	100									Clayey sand SC	Note (cc)	18
13	38.0	10.7	25	13			16	25	42	51	62	76	93	100								Clayey gravelly sand SC	Note (dd)	12
14	42.0	10.0					14	20	29	41	58	77	87	97	100							Silty gravelly sand SM	Note (ee)	
15	44.0	8.9					Broken jar															-	-	
16	46.0	11.1					12	22	34	43	67	87	97	100			1.9	0.31	0.06	31.7	0.84	Silty sand SM-SP	Note (ff)	
17	48.0	11.7					14	23	31	36	51	85	95	98	100							Silty gravelly sand SM	Note (ee)	
18	50.0	9.4					12	20	29	35	52	77	91	97	100		2.6	0.46	0.058	44.8	1.4	Silty gravelly sand SM-SW	Note (gg)	
19	52.0	21.4					10	20	63	77	87	98	100				0.40	0.24	0.080	5.0	1.8	Silty sand SM-SP	Note (hh)	
20	54.0	16.6					15	23	45	64	83	95	100									Silty sand SM	Note (ii)	
21	56.0	14.9					13	21	42	64	80	92	97	100								Silty sand SM	Note (ii)	
22	58.0	10.3					13	17	25	32	52	79	94	100								Silty gravelly sand SM	Note (ee)	
23	60.0	10.6					11	18	28	37	54	80	91	100			2.4	0.54	0.073	32.9	0.74	Silty gravelly sand SM-SP	Note (jj)	
24	62.0	11.0					18	24	31	39	55	79	90	96	100							Silty gravelly sand SM	Note (kk)	
25	64.0	17.3																				Shale CH	Note (ll)	
26	66.0	19.8																				Shale CH	Note (mm)	

Table E-2

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal		Boring No: 82-13	MRD Lab. No: 82/149
Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd Analysis Fines 005	02mm	U.S. Standard Sieve Sizes 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67		Remarks	Pl.
1	1.9	17.3	40	24																		Lean clay	CL	Note (o)	16
2	5.6	8.5																				Silty sand	SM	Note (p)	
3	10.6	18.7	49	34			82	89	94	98	100											Lean clay	CL	Note (q)	15
4	15.6	18.3	51	33																		Fat clay	CH	Note (r)	18
5	20.9	18.9																				Lean clay	CL	Note (s)	
6	25.8	16.6																				Fat clay	CH	Note (g)	
7	30.6	27.0																				Fat clay	CH	Note (m)	
8	35.5	–																				Clayey sand	SC	Note (t)	
9	36.4						9	14	28	53	76	93	97	100			1.1	0.43	0.10	11.0	1.7	Silty sand	SM-SW	Note (u)	
10	40.5	12.2																				Gravelly sand	SP	Note (v)	
11	40.8	–					8	12	19	27	48	75	89	100			2.8	0.98	0.11	25.5	3.1	Silty gravelly sand	SM-SP	Note (w)	
12	45.8	5.0																				gravelly sand	SP	Note (x)	
13	50.5	19.0					8	13	25	45	75	91	96	100			1.2	0.50	0.13	9.2	1.6	Silty sand	SM-SW	Note (y)	
14	51.0	–																				Silty sand	SM-SW	Note (y)	
15	55.5	11.1																				Silty gravelly sand	SM	Note (z)	
16	60.8	9.0					12	17	26	34	47	66	76	85	100		3.5	0.60	0.064	54.7	1.6	Silty gravelly sand	SM-SW	Note (aa)	
17	65.6	21.2																				Shale	CH	Note (n)	

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Table K-2

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal			Boring No: W-1	MRD Lab. No: 82/149
Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	.02mm	U. S. Standard Sieve Sizes 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification *Tech. MEMO 3-357, May 67*	Remarks	PL
1	2.0		35	19																		Lean clay CL	Note (h)	16
2	4.0																					Sandy clay CL	Note (i)	
3	6.0																					Sandy clay CL	Note (i)	
4	12.0																					Sandy clay CL	Note (i)	
5	14.0		57	31																		Fat clay CH	Note (j)	20
6	20.0																					Sandy clay CL	Note (i)	
7	22.0		44	29																		Lean clay CL	Note (k)	15
8	26.0																					Lean clay CL	Note (k)	
9	28.0								Lost in testing													Silty gravelly sand SM-SP	Note (l)	
10	32.0																					Fat clay CH	Note (m)	
11	36.0																					Fat clay CH	Note (m)	
12	37.3																					Sandy clay CL	Note (n)	
13	38.0						17	26	44	51	57	67	91	100								Silty gravelly sand SM	Note (o)	
14	42.0						9	15	24	38	57	72	84	97	100		2.3	0.89	0.070	32.9	4.9	Silty gravelly sand SM-SP	Note (p)	
15	–							Broken jar														–	–	
16	46.0						13	24	38	48	68	84	96	100								Silty gravelly sand SM	Note (q)	
17	48.0						13	23	36	43	62	81	94	98	100							Silty gravelly sand SM	Note (q)	
18	50.0						14	24	35	42	58	72	88	97	100							Silty gravelly sand SM	Note (q)	
19	52.0						11	21	70	84	92	97	100				0.32	0.20	0.080	4.6	1.9	Silty sand SM-SP	Note (r)	
20	–						15	26	51	72	86	94	100									Silty sand SM	Note (s)	
21	56.0						13	22	50	71	85	91	95	97	100							Silty sand SM	Note (t)	
22	58.0						18	26	37	47	60	72	92	100								Silty gravelly sand SM	Note (u)	
23	60.0						13	20	30	41	57	70	86	100								Silty gravelly sand SM	Note (u)	
24	62.0						13	19	31	43	62	74	87	94	100							Silty gravelly sand SM	Note (u)	
25	64.0																					Shale CH	Note (v)	
26	66.0																					Shale CH	Note (v)	

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Table G-2

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: SE-1	MRD Lab. No: 82/149
Station: – / Range: – / Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	P.I.	Hyd. Analsis Fines .005	02mm	U.S. Standard Sieve Sizes 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks	PL
1	0.8	7.2	29	13																		Lean clay CL	Note (a)	16
2	4.0	11.0																				Lean clay CL	Note (a)	
3	6.0	7.7																				Sandy clay CL	Note (b)	
4	12.0	19.9																				Sandy clay CL	Note (b)	
5	16.0	15.1																				Sandy clay CL	Note (b)	
6	20.0	18.1	41	27																		Lean clay CL	Note (c)	14
7	26.0	19.1																				Lean clay CL	Note (c)	
8	30.0	18.4																				Sandy clay CL	Note (b)	
9	36.0	22.5						Broken Jar														–	–	
10	38.0	3.4					17	22	31	45	67	82	97	100								Silty gravelly sand SM	Note (d)	
11	40.0	6.4					12	19	35	57	75	85	97	100			0.97	0.32	0.040	24.3	1.5	Silty gravelly sand SM-SW	Note (e)	
12	42.0	8.7					13	19	28	37	49	60	71	83	100							Silty gravelly sand SM	Note (f)	
13	44.0	10.5					15	23	34	45	57	67	78	96	100							Silty gravelly sand SM	Note (g)	
14	46.0	14.4					13	21	48	67	80	89	97	100								Silty sand SM	Note (h)	
15	48.0	11.8					11	18	30	46	64	78	93	100			1.7	0.40	0.074	23.0	1.3	Silty gravelly sand SM-SW	Note (i)	
16	50.0	13.1					6	16	30	46	65	81	95	100			1.6	0.40	0.11	14.6	0.91	Silty gravelly sand SM-SP	Note (j)	
17	52.0	10.7					8	14	22	34	53	77	92	98	100		2.4	0.75	0.15	16.0	1.6	Silty gravelly sand SM-SW	NOte (k)	
18	54.0	10.4					15	21	28	36	50	68	84	95	100							Silty gravelly sand SM	Note (l)	
19	56.0	9.0					13	20	28	37	56	81	95	100								Silty gravelly sand SM	Note (m)	
20	58.0	10.2					7	11	16	23	42	69	86	100			3.5	1.3	0.15	23.3	3.2	Silty gravelly sand SM-SP	Note (n)	
21	60.0	9.5					9	13	19	25	43	71	87	98	100		3.4	1.1	0.10	34.0	3.6	Silty gravelly sand SM-SP	Note (n)	
22	62.0	9.8					15	21	29	37	54	71	85	100								Silty gravelly sand SM	Note (o)	
23	64.0	22.3																				Shale CH	Note (p)	
24	66.0	22.0																				Shale CH	Note (p)	

MRD FORM NOV. 75 16 EDITION OF MAY 73 IS OBSOLETE

Table II-1

SOIL CLASSIFICATION RECORD SHEET

Project:	Rocky Mountain Arsenal	Boring No: SE-2 and NW-3	MRD Lab. No: 82/149
Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –
			Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Hyd. Analsis Fines .005	Hyd. Analsis Fines 02mm	U.S. Standard Sieve Sizes 200	Sand 60	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks	PI:
Hole SE-2																								
1	2.8	11.6	36	23			64	76	89	96	99	100										Sandy clay CL	Note (a)	13
2	6.1	6.2																				Clayey sand SC	Note (b)	
3	16.0	17.7	50	36																		Fat clay CH	Note (c)	14
4	26.2	21.7	57	40			72	81	88	91	95	99	100									Sandy clay CH	Note (d)	17
5	35.3	–																				Sandy clay CL	Note (e)	
6	36.2	2.6					8	11	15	27	50	82	95	100			2.4	0.93	0.13	18.5	2.8	Silty gravelly sand SM-SW	Note (f)	
7	45.5	8.7																				Sand SP	Note (g)	
8	55.3	4.6					9	13	20	29	55	85	100				2.3	0.87	0.088	26.1	3.7	Silty gravelly sand SM-SP	Note (h)	
9	66.3	19.7																				Shale CH	Note (i)	
Hole NW-3																								
1	1.5	9.6					56	71	89	97	100											Sandy clay CL	Note (j)	13
2	3.8	7.4	43	30																		Clayey sand SC	Note (k)	
3	13.6	22.2	55	40			82	91	98	99	100											Fat clay CH	Note (l)	15
4	39.4	7.3																				Sand SP	Note (m)	
5	43.8	9.7					6	10	16	24	44	74	89	97	100		3.2	1.1	0.17	18.8	2.2	Silty gravelly sand SM-SW	Note (n)	
6	45.8	12.5																				Silty sand SM-SP	Note (o)	
7	53.9	5.9					42	43	46	52	67	80	97	100								Silty gravelly sand SM	Note (p)	
8	57.8	10.0																				Silty gravelly sand SM	Note (q)	
9	60.5	7.5																				Silty gravelly sand SM	Note (q)	
10	62.0	19.1																				Shale CH	Note (r)	

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Table S-1

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal			Boring No: NW-1	MRD Lab. No: 82/149
Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Anaisis Fines .005	Fines .02mm	U. S. Standard Sieve Sizes Fines 200	Sand 60	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67		Remarks	Pl.
1	2.0	7.7																				Sandy clay	CL	Note (q)	
2	4.0	7.6																				Sandy clay	CL	Note (q)	
3	6.0	6.9																				Sandy clay	CL	Note (q)	
4	8.0	16.4	47	32																		Lean clay	CL	Note (r)	15
5	12.0	18.8																				Lean clay	CL	Note (r)	
6	14.0	8.6																				Clayey sand	SC	Note (s)	
7	16.0	18.4																				Sandy clay	CL	Note (t)	
8	20.0	20.0																				Sandy clay	CL	Note (t)	
9	22.0	18.4																				Lean clay	CL	Note (o)	
10	26.0	16.6																				Sandy clay	CL	Note (t)	
11	30.0	21.9																				Sandy clay	CL	Note (t)	
12	34.0	17.9																				Sandy clay	CL	Note (u)	
13	36.0	7.9					5	9	16	24	39	62	79	93	100		4.6	1.2	0.16	28.8	2.0	Gravelly sand	SW	Note (v)	
14	38.0	15.0					6	11	29	45	72	92	98	100			1.4	0.43	0.16	8.8	0.83	Silty sand	SM-SP	Note (w)	
15	40.0	9.5					32	37	44	55	62	81	95	100								Silty gravelly sand	SM	Note (x)	
16	42.0	11.1					4	7	15	26	48	70	88	98	100		3.3	1.0	0.25	13.2	1.2	Gravelly sand	SW	Note (y)	
17	42.3	9.9					16	30	58	76	88	93	95	100								Silty sand	SM	Note (z)	
18	44.0	9.7					12	17	24	32	53	80	93	100			2.5	0.68	0.058	43.1	3.2	Silty gravelly sand	SM-SP	Note (aa)	
19	45.9	13.8					12	18	24	32	46	66	87	97	100		3.6	0.78	0.072	50.0	2.3	Silty gravelly sand	SM-SW	Note (bb)	
20	48.0	13.7					18	24	36	48	69	90	96	100								Silty sand	SM	Note (cc)	
21		13.7					26	32	44	63	82	90	96	100								Silty sand	SM	Note (dd)	
22		18.5					7	15	57	70	92	98	100				0.44	0.25	0.11	4.0	1.3	Silty sand	SM-SP	Note (ee)	
23	52.0	13.6					13	21	31	45	63	80	90	95	100							Silty gravelly sand	SM	Note (ff)	
24	54.0	11.3					10	15	25	37	63	68	82	90	100		2.8	0.58	0.074	37.8	1.6	Silty gravelly sand	SM-SW	Note (gg)	
25	56.0	12.1					6	10	14	21	41	78	95	100			3.0	1.2	0.17	17.6	2.8	Silty gravelly sand	SM-SW	Note (hh)	
26	58.0	12.3					15	22	32	45	65	84	94	97	100							Silty gravelly sand	SM	Note (ii)	
27	60.0	22.8																				Shale	CH	Note (p)	
28	62.0	18.1																				Shale	CH	Note (p)	

MRD FORM NOV. 75 16 EDITION OF MAY 70 IS OBSOLETE

Table II-2

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal			Boring No: NW-2	MRD Lab. No: 82/149
Station: -	Range: -	Surf. Elev: -	Depth To Water Table: -	Bottom Of Hole: -

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer): Hyd. Analysis, Fines .005	Fines .02mm	U.S. Standard Sieve Sizes: Fines 200	Sand 80	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis: D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67		Remarks	PI.
1	2.0	7.3																				Sandy clay	CL	Note (a)	
2	6.0	5.7																				Sandy clay	CL	Note (a)	
3	8.0	8.2																				Sandy clay	CL	Note (a)	
4	12.0	22.2	47	32																		Lean clay	CL	Note (b)	15
5	14.0	7.9																				Clayey sand	SC	Note (c)	
6	16.0	18.9																				Sandy clay	CH	Note (d)	
7	22.0	20.5																				Lean clay	CL	Note (e)	
8	25.0	21.8	55	31																		Fat clay	CH	Note (f)	24
9	32.0	22.5																				Lean clay	CL	Note (b)	
10	38.0	18.2																				Clayey sand	SC	Note (c)	
11	40.0	9.7					18	27	38	49	61	70	78	85	100							Silty gravelly sand	SM	Note (g)	
12	42.0	9.7					9	13	20	27	39	55	68	78	100		6.2	1.1	0.10	62.0	2.0	Silty gravelly sand	SM-SW	Note (h)	
13	44.0	7.3					17	27	38	48	60	70	79	90	100							Silty gravelly sand	SM	Note (i)	
14	46.0	10.9					9	14	22	33	57	79	89	96	100		2.2	0.78	0.088	25.0	3.1	Silty gravelly sand	SM-SP	Note (j)	
15	48.0	10.8					20	29	43	58	74	85	95	100								Silty gravelly sand	SM	Note (k)	
16	50.0	11.5					12	18	28	44	74	88	96	100			1.3	0.47	0.047	27.7	3.6	Silty sand	SM-SP	Note (l)	
17	52.0	10.4					11	18	31	47	74	91	98	100			1.4	0.42	0.058	24.1	2.2	Silty sand	SM-SW	Note (m)	
18	54.0	11.4					11	16	25	35	62	86	96	100			1.9	0.60	0.063	30.2	3.0	Silty sand	SM-SW	Note (n)	
19	56.0	9.9					11	16	27	37	55	81	93	100			2.5	0.55	0.063	39.7	1.9	Silty gravelly sand	SM-SW	Note (o)	
20	58.0	9.5					21	31	43	50	60	71	84	94	100							Silty gravelly sand	SM	Note (p)	
21	60.0	22.2																				Shale	CH	Note (q)	
22	62.5	14.8																				Shale	CH	Note (q)	

MRD FORM 16
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Table J-1

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: 82-13A	MRD Lab. No: 82/149

Station: –	Range: –	Surf. Elev: –	Depth To Water Table:	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	Fines .02mm	U.S. Standard Sieve Sizes 200	Sand 80	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67		Remarks	PL
1	1.4	10.4																				Sandy clay	CL	Note (a)	
2	5.4	5.1																				Clayey sand	SC	Note (b)	
3	10.6	14.5	60	38																		Fat clay	CH	Note (c)	22
4	10.9	–																				Fat clay	CH	Note (c)	
5	16.1	16.8																				Fat clay	CH	Note (c)	
6	20.6	19.1																				Silty sand	SM	Note (d)	
7	21.4	–	30	15																		Lean clay	CL	Note (e)	15
8	25.7	20.4																				Lean clay	CL	Note (e)	
9	30.7	28.6	78	51																		Fat clay	CH	Note (f)	27
10	35.7	3.9					7	13	29	43	64	87	98	100			1.7	0.42	0.12	14.2	0.86	Silty sand	SM-SP	Note (g)	
11	36.4	–																				Gravelly sand	SP	Note (h)	
12	40.3	12.4					4	11	30	48	76	90	97	100			1.3	0.43	0.16	8.1	0.89	Sand	SP	Note (i)	
13	40.8	–																				Silty gravelly sand	SM-SP	Note (j)	
14	45.4	8.6																				Sand	SP	Note (i)	
15	45.9	–					6	10	16	26	49	84	96	100			2.6	0.96	0.15	17.3	2.4	Silty gravelly sand	SM-SW	Note (k)	
16	50.3	9.9																				Sand	SP	Note (l)	
17	50.9	–					10	17	29	44	77	92	97	100			1.3	0.43	0.082	15.9	1.7	Silty sand	SM-SW	Note (m)	
18	55.6	17.2																				Silty gravelly sand	SM-SW	Note (n)	
19	60.4	24.2					10	20	69	91	95	98	99	100			0.38	0.25	0.074	5.1	2.2	Silty sand	SM-SP	Note (o)	
20	61.0	–																				Silty sand	SM-SP	Note (o)	
21	66.1	25.1																				Shale	CH	Note (p)	

MRD FORM 16
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Table I-1

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal		Boring No: 82-13C	MRD Lab. No: 82/149
Station: –	Range: – / Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	Hyd. Analysis Fines .02mm	U.S. Standard Sieve Sizes Fines 200	Sand 60	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks	PL
1	2.0	8.0	41	27																		Lean clay CL	Note (a)	14
2	4.0	7.3																				Sandy clay CL	Note (b)	
3	8.0	7.9																				Lean clay CL	Note (a)	
4	15.0	12.7																				Clayey sand SC	Note (c)	
5	18.0	19.6	53	33																		Fat clay CH	Note (d)	20
6	28.0	23.5																				Sandy clay CL	Note (e)	
7	29.6	14.3																				Sandy clay CL	Note (e)	
8	32.0	26.2	58	39																		Fat clay CL	Note (f)	19
9	34.0	16.0																				Sandy clay CL	Note (e)	
10	36.0	4.3					12	20	24	32	55	83	100				2.4	0.78	0.050	48.0	5.1	Silty gravelly sand SM-SP	Note (g)	
11	38.0	6.6					5	8	15	31	65	86	95	100			1.8	0.80	0.20	9.0	1.8	Sand SW	Note (h)	
12	40.0	9.0					6	12	22	32	45	68	82	88	100		3.7	0.74	0.12	30.8	1.2	Silty gravelly sand SM-SW	Note (i)	
13	42.0	8.9					10	15	24	32	45	64	77	95	100		3.8	0.76	0.087	43.7	1.7	Silty gravelly sand SM-SW	Note (j)	
14	44.0	18.8					14	27	58	80	92	99	100									Silty sand SM	Note (k)	
15	46.0	16.3					9	13	25	41	68	90	99	100			1.7	0.45	0.11	15.5	1.1	Silty sand SM-SW	Note (l)	
16	48.0	12.6					16	22	32	47	77	95	100									Silty sand SM	Note (m)	
17	50.0	11.8					9	14	23	30	53	88	100				2.4	0.80	0.090	26.7	3.0	Silty sand SM-SW	Note (n)	
18	52.0	10.1					15	24	31	37	55	86	95	100								Silty sand SM	Note (o)	
19	54.0	14.0					7	11	24	40	63	83	92	97	100		1.8	0.55	0.15	12.0	1.1	Silty gravelly sand SM-SW	Note (p)	
20	56.0	10.6					5	9	15	75	50	83	94	100			2.6	1.1	0.16	16.3	2.9	Gravelly sand SW	Note (q)	
21	58.0	11.2					4	6	10	20	45	74	83	92	100		3.0	1.2	0.40	7.5	1.2	Gravelly sand SW	Note (r)	
22	60.0	12.1					12	18	27	38	53	85	93	96	100		2.2	0.50	0.074	29.7	1.5	Silty gravelly sand SM-SW	Note (s)	
23	62.0	11.3					10	16	24	35	56	83	93	100			2.3	0.62	0.072	31.9	2.3	Silty gravelly sand SM-SW	Note (t)	
24	64.0	22.5																				Shale CH	Note (u)	
25	67.0	18.4																				Shale CH	Note (u)	

MRD FORM 16
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Table F-1

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal		Boring No: 82-13B and 82-14	MRD Lab. No: 82/149
Station: –	Range: –	Surf. Elev: –	Depth To Water Table:	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	.02mm	U.S. Standard Sieve Sizes 200	Sand 60	40	20	10	4	Gravel 3/8	3/4	1½	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67		Remarks	PI.
Hole 82-13B																									
1	1.4	6.7																				Sandy clay	CL	Note (q)	
2	5.7	5.7																				Clayey sand	SC	Note (r)	
3	10.6	17.4	54	36																		Fat clay	CH	Note (s)	18
4	15.7	16.9																				Lean clay	CL	Note (t)	
5	20.4	23.8																				Fat clay	CH	Note (s)	
6	20.9	–																				Silty sand	SM-SP	Note (o)	
7	25.6	19.2																				Lean clay	CL	Note (t)	
8	30.5	26.1	70	46																		Fat clay	CH	Note (u)	24
9	35.3	–					30	51	84	96	100											Silty sand	SM	Note (w)	
10	36.1	8.3																				Gravelly sand	SP	Note (x)	
11	40.8	8.8					11	17	27	38	63	71	84	93	100		2.8	0.52	0.070	40.0	1.4	Silty gravelly sand	SM-SW	Note (y)	
12	45.6	9.4					9	14	20	29	50	78	96	98	100		2.7	0.80	0.088	30.7	2.7	Silty gravelly sand	SM-SW	Note (z)	
13	46.2	–																				Silty gravelly sand	SM-SP	Note (aa)	
14	44.6	–																				Silty sand	SM-SP	Note (bb)	
15	65.9	23.1																				Shale	CH	Note (p)	
Hole 82-14																									
1	2.0	11.0																				Fat clay	CH	Note (c)	
2	5.5	7.8	31	16			49	73	92	98	100											Sandy clay	CL	Note (cc)	15
3	5.8	–																				Sandy clay	CL	Note (cc)	
4	10.7	15.0	63	44			86	92	96	99	100											Fat clay	CH	Note (dd)	19
5	15.9	16.9																				Fat clay	CH	Note (dd)	
6	20.7	15.4																				Fat clay	CH	Note (s)	
7	25.9	19.6																				Fat clay	CH	Note (s)	
8	30.5	18.8					Broken jar															–		–	
9	38.8	9.4					12	17	41	79	93	98	100				0.56	0.30	0.050	11.6	3.1	Silty sand	SM-SP	Note (ee)	
10	40.3	16.0																				Silty sand	SM-SP	Note (ee)	
11	40.7	–					15	39	74	88	92	98	100									Silty sand	SM	Note (ff)	
12	50.3	–																				Fat clay	CH	Note (s)	
13	50.9	32.0																				Lean clay	CL	Note (gg)	
14	55.4	23.5					13	23	42	62	78	88	95	100								Silty sand	SM	Note (hh)	
15	55.8	–					Broken jar															–		–	
16	60.6	16.9																				Sandstone	SM	Note (ii)	
17	61.2	–																				Shale	CH	Note (p)	

Table 1-2

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: 82-15 and 82-16	MRD Lab. No: 82/149

Station: -	Range: -	Surf. Elev: -	Depth To Water Table: -	Bottom Of Hole: -

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	.02mm	U.S. Standard Sieve Sizes 200	Sand 60	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67		Remarks	PL
Hole 82-15																									
1	2.0	6.2	27	16			57	68	83	96	100											Sandy clay	CL	Note (a)	11
2	4.0	8.2																				Sandy clay	CL	Note (b)	
3	6.0	11.1	59	38																		Fat clay	CH	Note (c)	21
4	14.0	5.7					45	62	85	92	95	99	100									Silty sand	SM	Note (d)	
5	18.0	2.6					13	21	49	70	85	98	100									Silty sand	SM	Note (e)	
6	20.0	16.4	52	33																		Fat clay	CH	Note (f)	19
7	32.0	10.3																				Clayey gravelly sand	SC	Note (g)	
8	40.0	13.7	33	20			33	46	66	76	86	95	100									Clayey sand	SC	Note (h)	13
9	42.0	7.7					3	5	12	25	42	70	82	90	100		3.5	1.1	0.37	9.5	0.93	Gravelly sand	SP	Note (i)	
10	44.6	8.4					Broken jar															-		-	
11	47.9	22.6																				Shale	CH	Note (j)	
Hole 82-16																									
1	2.0	12.5																				Clayey sand	SC	Note (k)	
2	5.9	12.4	30	19			53	73	94	100												Sandy clay	CL	Note (l)	11
3	10.9	11.3																				Clayey sand	SC	Note (m)	
4	16.0	18.3	51	31			60	75	88	96	99	100										Sandy clay	CH	Note (n)	20
5	20.9	13.7	36	21			59	72	86	92	95	99	100									Sandy clay	CL	Note (o)	15
6	25.9	13.1																				Sandy clay	CL	Note (o)	
7	30.9	10.7																				Sandy clay	CL	Note (o)	
8	36.0	25.4																				Lean clay	CL	Note (p)	
9	41.2	2.3					9	15	27	43	60	75	89	100			1.9	0.45	0.085	22.4	1.3	Silty gravelly sand	SM-SW	Note (q)	
10	45.8	7.7					5	8	15	34	55	70	81	92	100		2.6	0.80	0.26	10.0	0.95	Gravelly sand	SP	Note (r)	
11	50.3	-																				Sandstone	SM	Note (s)	
12	51.2	26.1																				Shale	CH	Note (j)	
13	56.2	24.9																				Shale	CH	Note (j)	

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Table M-1

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal | Boring No: 82-16A | MRD Lab. No: 82/149

Station: - | Range: - | Surf. Elev: - | Depth To Water Table: - | Bottom Of Hole: -

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	Fines .02mm	U.S. Standard Sieve Sizes 200	Sand 60	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67		Remarks	PL
1	2.0																					Fat clay	CH	Note (t)	
2	3.0		26	16			49	62	81	92	98	100										Clayey sand	SC	Note (u)	10
3	6.0																					Sandy clay	CL	Note (v)	
4	8.0		42	26			53	65	86	98	100											Sandy clay	CL	Note (w)	16
5	12.0																					Fat clay	CH	Note (f)	
6	14.0		46	28			57	73	89	94	96	98	100									Sandy clay	CL	Note (x)	18
7	18.0																					Lean clay	CL	Note (y)	
8	26.0		47	28																		Lean clay	CL	Note (z)	19
9	28.0		37	25			27	41	65	77	86	95	100									Clayey sand	SC	Note (aa)	12
10	30.0																					Sandy clay	CL	Note (bb)	
11	34.0																					Sandy gravelly clay	CL	Note (cc)	
12	41.0						10	16	30	47	63	81	93	96	100		1.8	0.40	0.070	25.7	1.3	Silty gravelly sand	SM-SW	Note (dd)	
13	46.0																						-	-	
14	50.0																					Shale	CH	Note (g)	

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: 82-17 and 82-18	MRD Lab. No: 82/149
Station: – Range: – Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	.02mm	U.S. Standard Sieve Sizes 200	Sand 60	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks	Pl.
Hole 82-17																								
1	2.0		41	26																		Lean clay CL	Note (a)	15
2	4.0						43	58	80	91	93	98	100									Silty sand SM	Note (b)	
3	6.0																					Sandy clay CL	Note (c)	
4	12.0		42	29			64	73	87	94	97	100										Sandy clay CL	Note (d)	13
5	14.0																					Sandy clay CL	Note (d)	
6	16.0																					Sandy clay CL	Note (d)	
7	18.0																					Sandy clay CL	Note (d)	
8	22.0		33	20																		Lean clay CL	Note (e)	13
9	36.0																					Sandy clay CL	Note (f)	
10	40.0																					Lean clay CL	Note (e)	
11	42.0																					Fat clay CH	Note (g)	
12	44.0						14	18	24	32	48	67	79	90	100							Silty gravelly sand SM	Note (h)	
13	46.0																					Sandstone CM	Note (i)	
Hole 82-18																								
1	1.7		46	32			65	76	90	97	99	100										Sandy clay CL	Note (j)	14
2	6.2		40	26			60	69	84	95	99	100										Sandy clay CL	Note (k)	14
3	11.3		57	42			73	82	94	98	100											Sandy clay CL	Note (l)	15
4	15.9																					Sancy clay CL	Note (j)	
5	21.2																					Sandy clay CL	Note (k)	
6	26.6		36	23			61	76	87	93	98	100										Sandy clay CL	Note (m)	13
7	31.2																					Sandy clay CL	Note (m)	
8	36.4		41	27			65	72	80	87	93	98	100									Sandy clay CL	Note (n)	14
9	40.3																					Sandy clay CL	Note (j)	
10	41.9						8	12	17	24	41	67	84	96	100		3.8	1.1	0.12	31.7	2.7	Silty gravelly sand SM-SW	Note (o)	
11	45.8																					Sandstone	Note (p)	
12	51.2																					Shale CH	Note (q)	
13	56.2																					Shale CH	Note (q)	

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal | Boring No: 82-19 and 82-20 | MRD Lab. No: 82/149

Station: – | Range: – | Surf. Elev: – | Depth To Water Table: – | Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	Fines .02mm	U.S. Standard Sieve Sizes 200	Sand 80	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
Hole 82-19																							
1	2.3		35	22			84	93	99	100												Lean clay CL	Note (r) 13
2	6.3																					Lean clay CL	Note (r)
3	11.5																					Sandy clay CH	Note (l)
4	16.4																					Sandy clay CL	Note (l)
5	21.2																					Clayey sand SC	Note (s)
6	25.3																					Sandy clay CL	Note (t)
7	25.8						18	25	37	48	60	72	81	94	100							Silty gravelly sand SM	Note (u)
8	31.3																					Shale CH	Note (q)
9	35.9																					Shale CH	Note (q)
10	40.9																					Shale CH	Note (q)
Hole 82-20																							
1	2.3		37	23																		Lean clay CL	Note (v) 14
2	6.3		36	23			46	59	81	94	100											Clayey sand SC	Note (w) 13
3	10.7																					Lean clay CL	Note (x)
4	15.6		48	33			77	86	93	96	98	100										Sandy clay CL	Note (y) 15
5	20.3																					Clayey sand SC	Note (w)
6	20.9						6	11	26	39	55	73	87	100			2.4	0.49	0.15	16.0	0.67	Silty gravelly sand SM-SP	Note (z)
7	25.3						7	10	19	30	48	77	90	93	100		2.7	0.88	0.16	16.9	1.8	Silty gravelly sand SM-SW	Note (aa)
8	26.0						Broken jar															–	–
9	30.4						6	12	32	56	74	85	93	100			0.90	0.40	0.15	6.0	1.2	Silty gravelly sand SM-SW	Note (bb)
10	31.3																					Silty sandy gravel GM-GP	Note (cc)
11	35.4						8	12	21	32	49	73	87	100			2.8	0.78	0.12	23.3	1.8	Silty gravelly sand SM-SW	Note (dd)
12	36.5																					Shale CH	Note (q)
13	41.8																					Shale CH	Note (q)

MRD FORM NOV. 76 16 EDITION OF MAY 70 IS OBSOLETE

Table N-2

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal
Boring No: 82-22
MRD Lab. No: 82/149
Station: –
Range: –
Surf. Elev: –
Depth To Water Table: –
Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	.02mm	U.S. Standard Sieve Sizes Fines 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks	PI.
1	1.5	3.5	26	16			63	77	95	100												Sandy clay CL	Note (a)	10
2	5.5	5.8																				Sandy clay CL	Note (a)	
3	10.6	7.9					40	67	97	100												Silty sand SM	Note (b)	
4	15.7	20.6	37	19																		Lean clay CL	Note (c)	18
5	20.8	18.4																				Lean clay CL	Note (c)	
6	25.5	10.4																				Lean clay CL	Note (c)	
7	30.4	9.5																				Sandy clay CL	Note (d)	
8	35.6	17.7	52	33																		Fat clay CH	Note (e)	19
9	41.0	0.9					6	10	19	31	52	74	89	93	100		2.6	0.83	0.16	16.3	1.7	Silty gravelly sand SM-SW	Note (f)	
10	45.7	10.8					11	17	24	34	50	66	85	100			3.5	0.63	0.073	47.9	1.6	Silty gravelly sand SM-SW	Note (g)	
11	50.7	29.0							No jar sample															

MRD FORM NOV. 75 16 EDITION OF MAY 70 IS OBSOLETE

Table G-1

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal | Boring No: 82-21 | MRD Lab. No: 82/149

Station: – | Range: – | Surf. Elev: – | Depth To Water Table: – | Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	.02mm	U.S. Standard Sieve Sizes 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks	PL
1	1.8	4.7	25	9			39	64	92	99	100											Clayey sand SC	Note (v)	16
2	5.6	3.0	19	8			23	46	89	100												Clayey sand SC	Note (w)	11
3	10.7	5.5																				Clayey sand SC	Note (w)	
4	16.5	5.3					21	43	79	98	100											Silty sand SM	Note (x)	
5	21.5	14.1																				Lean clay CL	Note (y)	
6	26.3	15.0	45	28																		Lean clay CL	Note (y)	17
7	32.0	10.7																				Sandy clay CL	Note (e)	
8	35.7	1.2					4	9	18	29	54	81	91	98	100		2.3	0.90	0.17	13.5	2.1	Gravelly sand SW	Note (z)	
9	41.7	3.5					15	22	32	42	59	82	90	94	100							Silty gravelly sand SM	Note (aa)	
10	46.0	5.3					13	20	33	49	71	88	94	97	100							Silty sand SM	Note (bb)	
11	49.4	8.7					Broken Jar															–	–	
12	50.0	18.7																				Lean clay CL	Note (y)	
13	52.0	9.2					11	16	25	37	49	64	75	86	100		3.8	0.58	0.058	65.5	1.5	Silty gravelly sand SM-SW	Note (cc)	
14	53.7	12.8																				Silty gravelly sand SM	Note (aa)	
15	56.0	12.3																				Silty gravelly sand SM	Note (aa)	
16	58.0	14.5																				Lean clay CL	Note (y)	
17	59.0	23.1																				Shale CH	Note (u)	

Table F-2

MRD FORM NOV. 75 16 EDITION OF MAY 70 IS OBSOLETE

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal		Boring No: 82-23 and 82-23A	MRD Lab. No: 82/149
Station: –	Range: –	Surf. Elev: – / Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis, Fines .005	Fines .02mm	U.S. Standard Sieve Sizes, Fines 200	Sand 60	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
Hole	82-23																						
1	2.0																					Silty sand SM	
2	4.0																					Silty sand SM	
3	10.0																					Sandy clay CL	
4	12.0																					Lean clay CL	
5	22.0																					Lean clay CL	
6	32.0																					Sandy clay CL	
7	36.0																					Lean clay CL	
8	46.0																					Silty gravelly sand SM	
9	61.0																					Sandy claystone CL	
10	64.0																					Clay shale sand volcanic	material mix.
Hole	82-23A																						
1	2.6																					Clayey sand SC	
2	6.6																					Silty sand SM	
3	11.7																					Silty sand SM-SP	
4	16.4																					Sandy clay CL	
5	21.1																					Fat clay CH	
6	26.3																					Sandy clay CL	
7	31.5																					Sandy clay CL	
8	36.4																					Lean clay CL	
9	41.4																					Sandy clay CL	
10	46.8																					Lean clay CL	
11	51.2																					Silty gravelly sand SM-SW	
12	56.1																					Silty sandy gravel GM-GP	
13	61.0																					Silty sand SM-SP	
14	61.3																					Shale CH	
15	66.3																					Shale CH	

Table P-1

MRD FORM 16
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SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: 82-24 and 82-24A	MRD Lab. No: 82/149
Station: – Range: – Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits)		Grading (Cumulative Percents Finer)												Gradation Curve Analysis					Classification Tech. MEMO 3-357, May 67	Remarks
					Hyd. Analysis		U. S. Standard Sieve Sizes																
					Fines			Sand					Gravel										
			L.L.	P.I.	.005	.02mm	200	60	40	20	10	4	3/8	3/4	1 1/2	3 in	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c		
Hole	82-24																						
1	2.2																					Clayey sand SC	
2	6.5																					Silty sand SM	
3	11.4																					Sandy clay CL	
4	16.9																					Sandy clay CL	
5	21.5																					Lean clay CL	
6	26.0																					Lean blay CL	
7	30.8																					Fat clay CH	
8	35.8																					Sandy clay CL	
9	41.3																					Lean clay CL	
10	46.1																					Silty gravelly sand SM-SP	
11	51.4																					Lean clay CL	
12	56.0																					Silty gravelly sand SM-SP	
13	61.2																					Shale CH	
Hole	82-24A																						
1	2.5																					Silty sand SM-SP	
2	6.0																					Silty sand SM-SP	
3	11.5																					Sandy clay CL	
4	16.3																					Sandy clay CL	
5	21.1																					Clayey sand SC	
6	26.7																					Sandy clay CL	
7	31.5																					Sandy clay CL	
8	36.4																					Sandy clay CL	
9	41.3																					Silty gravelly sand SM-SP	
10	45.6																					Silty gravelly sand SM-SP	
11	50.3																					Clayey gravelly sand SC	
12	51.8																					Shale CH	
13	56.3																					Shale CH	

MRD FORM 16 NOV. 75 EDITION OF MAY 70 IS OBSOLETE

Table P-2

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: 82-25 and 82-26	MRD Lab. No: 82/149

Station: –	Range: –	Surf. Elev: –	Depth To Water Table:	Bottom Of Hole:

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analsis Fines .005	Fines .02mm	U.S. Standard Sieve Sizes 200	Sand 60	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
Hole	82-25																						
1	1.7																					Silty sand SM	
2	6.5																					Silty sand SM	
3	11.2																					Fat clay CH	
4	16.2																					Lean clay CL	
5	21.5																					Lean clay CL	
6	26.0																					Lean clay CL	
7	31.6																					Sandy clay CH	
8	35.4																					Silty gravelly sand SM-SW	
9	36.8																					Sandstone	
10	41.3																					Sandy claystone CL	
Hole	82-26																						
1	1.9																					Clayey sand SC	
2	2.5																					Silty sand SM	
3	6.5																					Broken jar	
4	11.6																					Broken jar	
5	15.8																					Sandy clay CL	
6	16.3																					Sandy clay CL	
7	21.3																					Sandy clay CL	
8	26.2																					Sandy clay CH	
9	31.2																					Sandy clay CL	
10	36.4																					Lean clay CL	
11	41.3																					Shale CH	
12	46.4																					Shale CH	

MRD FORM 16
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Table P-3

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal		Boring No: 82-27 through 82-29	MRD Lab. No: 82/149
Station: -	Range: -	Surf. Elev: -	Depth To Water Table:	Bottom Of Hole: -

Sample No.	Depth To Bottom Of Sample	Moist-ure (%)	Plasticity (Att. Limits) L.L.	P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	.02mm	U. S. Standard Sieve Sizes 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
Hole	82-27																						
1	2.0																					Sandy clay CL	
2	5.7																					Sandy clay CL	
3	10.9																					Lean clay CL	
4	15.4																					Sandy clay CL	
5	20.4																					Sandy gravelly clay CL	
6	25.4																					Shale CH	
7	30.3																					Shale CH	
8	35.4																					Shale CH	
Hole	82-28																						
1																						Clayey sand SC	
2																						Sandy clay CL	
3																						Clayey sand SC	
4																						Silty gravelly sand SM-SP	
5																						Silty gravelly sand SM-SW	
6																						Shale CH	
7																						Shale CH	
Hole	82-29																						
1																						Clayey sand SC	
2																						Clayey sand SC	
3																						Sandy clay CL	
4																						Sandy clay CL	
5																						Clayey gravelly sand SC	
6																						Clayey gravelly sand SC	
7																						Silty gravelly sand SM-SP	
8																						Shale CH	
																						Shale CH	

MRD FORM NOV. 75 16 EDITION OF MAY 70 IS OBSOLETE

Table P-4

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal | Boring No: 82-30 and 82-31 | MRD Lab. No: 82/149

Station: – | Range: – | Surf. Elev: – | Depth To Water Table: – | Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis, Fines .005	.02mm	U.S. Standard Sieve Sizes 200	Sand 60	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
Hole	82-30																						
1	2.5																					Silty sand SM	
2	5.7																					Lean clay CL	
3	11.4																					Lean clay CL	
4	16.2																					Sandy clay CL	
5	21.5																					Gravelly sand SP	
6	26.4																					Silty gravelly sand SM-SP	
7	31.1																					Silty gravelly sand SM-SP	
8	36.3																					Shale CH	
9	41.0																					Shale CH	
Hole	82-31																						
1	1.7																					Sandy clay CL	
2	2.3																					Silty sand SM	
3	6.0																					Clayey sand SC	
4	11.2																					Clayey sand SC	
5	16.1																					Silty sand SM	
6	21.1																					Lean clay CL	
7	25.4																					Silty sand SM	
8	26.4																					Silty gravelly sand SM-SW	
9	31.3																					Fat clay CH	
10	35.9																					Gravelly sand SP	
11	41.0																					Sand SW	
12	46.6																					Sandstone	
13	51.0																					Shale CH	

Table P-5

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal | **Boring No:** 82-32 and 82-33 | **MRD Lab. No:** 82/149

Station: – | **Range:** – | **Surf. Elev:** – | **Depth To Water Table:** – | **Bottom Of Hole:** –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	Fines .02mm	U. S. Standard Sieve Sizes Fines 200	Sand 60	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
Hole	82-32																						
1	1.7																					Sandy clay CL	
2	6.3																					Sandy clay CL	
3	11.0																					Broken jar –	
4	16.3																					Silty sand SM	
5	21.2																					Silty sand SM	
6	25.8																					Clayey sand SC	
7	26.4																					Lean clay CL	
8	30.5																					Silty gravelly sand SM-SW	
9	31.2																					Silty sand SM	
10	35.8																					Sandy clay CL	
11	36.3																					Silty sand SM-SP	
12	40.9																					Silty gravelly sand SM-SW	
13	45.7																					Silty gravelly sand SM-SW	
14	46.6																					Shale CH	
15	51.5																					Shale CH	
16	56.1																					Shale CH	
Hole	82-33																						
1	1.9																					Lean clay CL	
2	5.9																					Sandy clay CL	
3	10.8																					Lean clay CL	
4	16.2																					Silty sand SM	
5	21.3																					Silty sand ~~SC~~ SM	
6	26.2																					Clayey sand SC	
7	31.3																					Sandstone	
8	35.9																					Shale CH	

Table R-1

MRD FORM NOV. 75 16 EDITION OF MAY 70 IS OBSOLETE

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal | Boring No: 82-34 and 82-39 | MRD Lab. No: 82/149

Station: - | Range: - | Surf. Elev: - | Depth To Water Table: - | Bottom Of Hole: -

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	Fines .02mm	U.S. Standard Sieve Sizes 200	Sand 60	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
Hole	82-34																						
1																						Lean clay CL	
2																						Sandy clay CL	
3																						Sandy clay CL	
4																						Clayey sand SC	
5																						Shale CH	
6																						Silty sand SM	
7																						Shale CH	
Hole	82-39																						
1	2.1																					Broken jar	
2	6.5																					Clayey sand SC	
3	11.3																					Sandy clay CL	
4	16.3																					Lean clay CL	
5	21.3																					Fat clay CH	
6	26.5																					Fat clay CH	
7	31.4																					Fat clay CH	
8	36.5																					Lean clay CL	
9	40.3																					Gravelly sand SP	
10	45.9																					Silty gravelly sand SM-SP	
11	50.9																					Silty gravelly sand SM	
12	55.7																					Gravelly sand SW	
13	60.9																					Silty sand SM	
14	66.4																					Shale CH	

MRD FORM 16 NOV. 75 EDITION OF MAY 70 IS OBSOLETE

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: 82-41 and 82-42	MRD Lab. No: 82/149

Station: -	Range: -	Surf. Elev: -	Depth To Water Table: -	Bottom Of Hole: -

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Anolsis Fines .005	Fines .02mm	U.S. Standard Sieve Sizes Fines 200	Sand 80	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification *Tech. MEMO 3-357, May 67*	Remarks
Hole	82-41																						
1	2.5																					Silty sand SM	
2	6.4																					Silty sand SM-SP	
3	11.4																					Clayey sand SC	
4	16.4																					Clayey sand SC	
5	20.4																					Silty sand SM-SP	
6	21.5																					Sandy clay CL	
7	26.3																					Fat clay CH	
8	31.4																					Fat clay CH	
9	35.5																					Sandy clay CL	
10	36.5																					Lean clay CL	
11	41.5																					Lean clay CL	
12	46.3																					Silty gravelly sand SM-SP	
13	50.8																					Sand SP	
14	56.6																					Shale CH	
Hole	82-42																						
1	1.4																					Clayey sand SC	
2	1.8																					Lean clay CL	
3	8.0																					Lean clay CL	
4	18.0																					Sandy clay CL	
5	28.0																					Clayey sand SC	
6	36.0																					Lean clay CL	
7	38.0																					Clayey sand SC	
8	43.7																					Sand SP	
9	46.0																					Silty gravelly sand SM-SP	
10	49.0																					Shale CH	

MRD FORM NOV. 75 16 EDITION OF MAY 70 IS OBSOLETE

Table R-3

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal			Boring No: 82-43, 82-44 and 82-45	MRD Lab. No: 82/149
Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	.02mm	U.S. Standard Sieve Sizes 200	Sand 60	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
Hole	82-43																						
1	2.3																					Silty sand SM-SP	
2	6.5																					Sandy clay CL	
3	11.1																					Silty sand SM-SP	
4	15.8																					Sandy clay CL	
5	21.2																					Sand clay CL	
6	26.1																					Silty sand SM	
7	30.6																					Sandy clay CL	
8	36.1																					Clayey sand SC	
9	46.1																					Silty sand SM-SW	
10	51.6																					Shale CH	
Hole	82-44																						
1	2.7																					Silty sand SM	
2	6.2																					Sandy clay CL	
3	11.3																					Sandy clay CL	
4	16.5																					Lean clay CL	
5	21.5																					Sandy clay CL	
6	26.0																					Silty sand SM-SP	
7	31.0																					Silty sand SM-SP	
8	36.1																					Sandstone	
9	41.7																					Silty sandstone	
10	45.9																					Sandstone	
Hole	82-45																						
1																						Silty sand SM-SP	
2																						Sandy clay CL	
3																						Sandy clay CL	
4																						Sandy clay CL	
5																						Broken jar	
6																						Sandy clay CL	
7																						Silty gravelly sand SM-SP	
8																						Shale CH	
9																						Shale CH	

MRD FORM NOV. 75 16 EDITION OF MAY 70 IS OBSOLETE

Table R-4

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: 82-45A and 82-46	MRD Lab. No: 82/149

Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	Fines .02mm	U.S. Standard Sieve Sizes 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67		Remarks
Hole	82-45A																							
1	2.4																					Silty sand	SM	
2	5.9																					Sandy clay	CL	
3	11.1																					Sandy clay	CL	
4	16.3																					Sandy clay	CL	
5	20.8																					Sandy clay	CL	
6	21.4																					Weathered granite		
7	26.0																					Gravelly sand	SW	
8	30.3																					Clayey sand	SC	
9	31.3																					Silty sand	SM-SP	
10	36.2																					Sand	SW	
11	40.4																					Silty sand	SM-SP	
12	41.0																					Shale	CH	
13	45.9																					Shale	CH	
Hole	82-46																							
1																						Clayey sand	SC	
2																						Silty sand	CM-SM	
3																						Sandy clay	CL	
4																						Sandy clay	CL	
5																						Sandy clay	CL	
6																						Silty sand	SM	
7																						Silty sand	SM-SP	
8																						Shale	CH	
9																						Shale	CH	

MRD FORM 16 NOV. 76 EDITION OF MAY 70 IS OBSOLETE

Table R-5

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal

Boring No: 82-46A, 82-47 and 82-48

MRD Lab. No: 82/149

Station: -

Range: -

Surf. Elev: -

Depth To Water Table: -

Bottom Of Hole: -

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analsis Fines .005	Fines .02mm	U.S. Standard Sieve Sizes Fines 200	Sand 60	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
Hole	82-46A																						
1	2.0																					Silty sand SM	
2	6.6																					Clayey sand SC	
3	10.7																					Sandy clay CL	
4	16.5																					Sandy clay CL	
5	21.0																					Lean clay CL	
6	26.4																					Gravelly sand SW	
7	30.5																					Silty sand SM	
8	31.6																					Shale CH	
9	36.2																					Shale CH	
Hole	82-47																						
1	2.8																					Lean clay CL	
2	6.1																					Sandy clay CL	
3	11.4																					Sandy clay CL	
4	16.0																					Sand SW	
5	21.1																					Gravelly sand SW	
6	31.8																					Sandy silt ML	
7	36.8																					Shale CH	
Hole	82-48																						
1	1.4																					Fat clay CH	
2	6.5																					Lean clay CL	
3	10.4																					Sandy clay CL	
4	16.0																					Gravelly sand SW	
5	21.1																					Gravelly sand SW	
6	25.6																					Sandy gravel GP	
7	31.6																					Shale CH	

Table B-6

MRD FORM
NOV. 75 [illegible] EDITION OF MAY 70 IS OBSOLETE

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal

Boring No: 82-50 and 82-52 | **MRD Lab. No:** 83/75

Station: – | **Range:** – | **Surf. Elev:** – | **Depth To Water Table:** | **Bottom Of Hole:** –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	P.I.	Hyd. Analysis Fines .005	.02mm	Sieve 200	Sand 80	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
Hole	82-50																						
1	1.5																					Sandy clay CL	
2	5.4																					Sandy clay CL	
3	10.6																					Silty sand SM-SP	
4	16.0																					Sandy clay CL	
5	21.8																					Sandy clay CL	
6	27.0																					Fat clay CH	
7	31.7																					Silty sand SM	
8	36.1						5	14	22	31	47	58	73	91	100		4.5	0.68	0.078	57.7	1.3	Gravelly sand SW	
9	41.2																					Gravelly sand SW	
10	46.3						4	8	19	36	59	80	98	100			1.8	0.59	0.19	9.5	1.0	Gravelly sand SW	
11	51.5																					Silty gravelly sand SM-SW	
12	56.0																					Shale CH	
Hole	82-52																						
1	6.3																					Clayey sand SC	
2	11.2																					Silty sand SM-SP	
3	20.9																					Fat clay CH	
4	30.8																					Fat clay CH	
5	31.7																					Lean clay CL	
6	32.0																					Silty sand SM	
7	33.5						8	13	20	29	40	45	54	67	100		12.5	0.91	0.11	113.6	0.60	Silty sandy gravel GM-GP	
8	41.1																					Gravelly sand SW	
9	46.6						11	17	28	41	63	81	91	96	100		1.9	0.44	0.07	27.1	1.5	Silty gravelly sand SM-SW	
10	51.2																					Silty sand SM-SP	
11	52.5																					Shale CH	

MRD FORM NOV. 75 16 EDITION OF MAY 70 IS OBSOLETE

Table B-1

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal		Boring No: 82-56	MRD Lab. No: 83/75
Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits)		Grading (Cumulative Percents Finer)												Gradation Curve Analysis					Classification Tech. MEMO 3-357, May 67	Remarks
					Hyd. Analysis		U. S. Standard Sieve Sizes																
					Fines			Sand					Gravel										
			L.L.	P.I.	.005	.02mm	200	80	40	20	10	4	3/8	3/4	1 1/2	3 in	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c		
Hole	82-56																						
1	1.4																					Sandy clay CL	
2	6.1																					Lean clay CL	
3	10.5																					Sandy clay CL	
4	15.7																					Fat clay CH	
5	16.6																					Sandy clay CL	
6	21.0																					Sandy clay CL	
7	26.1																					Lean clay CL	
8	31.1																					Lean clay CL	
9	35.4																					Silty sandy gravel GM-GP	
10	36.1																					Silty sand SM-SP	
11	38.3						8	15	33	57	79	90	97	100			0.92	0.36	0.094	9.8	1.5	Silty sand SM-SW	
12	40.8																					Silty gravelly sand SM-SW	
13	41.5																					Silty sand SM-SP	
14	42.7																					Silty sand SM	
15	43.2																					Lean clay CL	
16	43.7						14	20	41	72	81	84	85	88	100							Silty gravelly sand SM	
17	44.5																					Shale CH	
18	47.0																					Shale CH	

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Table B-3

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal			Boring No: 82-57	MRD Lab. No: 83/75
Station: –	Range: –	Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits)		Grading (Cumulative Percents Finer)												Gradation Curve Analysis					Classification	Remarks
					Hyd. Anolsis		U. S. Standard Sieve Sizes																
					Fines			Sand					Gravel										
			L.L.	P.I.	.005	.02mm	200	60	40	20	10	4	3/8	3/4	1 1/2	3 in	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Tech. MEMO 3-357, May 67	
1	1.9																					Sandy clay CL	
2	5.5																					Lean clay CL	
3	10.6																					Lean clay CL	
4	16.1																					Sandy clay CL	
5	20.7																					Fat clay CH	
6	26.1																					Fat clay CH	
7	31.8																					Fat clay CH	
8	35.9																					Silty gravelly sand SM-SW	
9	36.5																					Silty gravelly sand SM-SW	
10	39.0						8	14	30	46	64	78	91	100			1.6	0.42	0.089	18.0	1.2	Silty gravelly sand SM-SW	
11	41.3																					Silty gravelly sand SM-SW	
12	43.4																					Silty gravelly sand SM-SW	
13	45.4						5	8	17	33	51	68	81	88	100		2.7	0.75	0.17	15.9	1.2	Gravelly sand SW	
14	46.1																					Shale CH	
15	48.1																					Shale CH	

MRD FORM 16 NOV. 75 EDITION OF MAY 70 IS OBSOLETE

Table B-4

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: 82-58	MRD Lab. No: 83/75
Station: – Range: – Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	.02mm	U.S. Standard Sieve Sizes Fines 200	Sand 60	Sand 40	Sand 20	Sand 10	Sand 4	Gravel 3/8	Gravel 3/4	Gravel 1 1/2	Gravel 3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
1	1.4																					Lean clay CL	
2	6.0																					Sandy clay CL	
3	10.6																					Sandy clay CL	
4	15.8																					Sandy clay CL	
5	20.6																					Silty sand SM	
6	25.9																					Lean clay CL	
7	31.7																					Fat clay CH	
8	33.5																					Lean clay CL	
9	37.0																					Sandy clay CL	
10	38.9																					Clayey sand SC	
11	39.2																					Silty sand SM	
12	40.9						16	22	31	37	49	56	70	87	100							Silty sandy gravel GM	
13	46.0						17	24	35	44	57	68	81	99	100							Silty gravelly sand SM	
14	48.4																					Shale CH	
15	51.0																					Shale CH	
16	56.0																					Shale CH	

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Table C-1

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal		Boring No: 83-59	MRD Lab. No: 83/75
Station: -	Range: -	Surf. Elev: -	Depth To Water Table: -	Bottom Of Hole: -

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	Plasticity (Att. Limits) P.I.	Grading (Cumulative Percents Finer) Hyd. Analysis Fines .005	.02mm	U.S. Standard Sieve Sizes 200	Sand 60	40	20	10	4	Gravel 3/8	3/4	1½	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67		Remarks
1	1.6																					Lean clay	CL	
2	5.7																					Silt	ML	
3	10.6																					Clayey sand	SC	
4	15.5																					Sandy clay	CL	
5	21.6																					Sandy clay	CL	
6	26.4																					Fat clay	CH	
7	31.3																					Sandy clay	CL	
8	34.4																					Sandy clay	CL	
9	35.9																					Sandy clay	CL	
10	36.6																					Clayey sand	SC	
11	38.8						10	16	31	47	68	84	96	99	100		1.5	0.37	0.080	18.8	1.1	Silty gravelly sand	SM-SW	
12	40.8																					Silty sand	SM	
13	41.4																					Gravelly sand	SW	
14	46.5						9	18	47	79	93	98	100				0.55	0.28	0.082	6.7	1.7	Silty sand	SM-SW	
15	48.0																					Shale	CH	
16	51.8																					Shale	CH	

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Table C-2

SOIL CLASSIFICATION RECORD SHEET

Project: Rocky Mountain Arsenal	Boring No: 82-60 and 82-61	MRD Lab. No: 83/75
Station: – / Range: – / Surf. Elev: –	Depth To Water Table: –	Bottom Of Hole: –

Sample No.	Depth To Bottom Of Sample	Moisture (%)	Plasticity (Att. Limits) L.L.	P.I.	Grading (Cumulative Percents Finer) Hyd. Analsis Fines .005	.02mm	U.S. Standard Sieve Sizes 200	Sand 60	40	20	10	4	Gravel 3/8	3/4	1 1/2	3 in	Gradation Curve Analysis D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	Classification Tech. MEMO 3-357, May 67	Remarks
Hole	82-60																						
1	1.4																					Sandy clay CL	
2	5.3																					Silty sand SM	
3	10.6																					Lean clay CL	
4	15.4																					Sandy clay CL	
5	21.0																					Sandy clay CL	
6	26.0																					Sandy clay CL	
7	28.8																					Sandy clay CL	
8	30.9						38	52	76	88	94	98	100									Clayey sand SC	
9	33.4																					Sandy clay CL	
10	35.8																					Sandy clay CL	
11	38.5																					Fat clay CH	
12	41.0																					Fat clay CH	
13	43.6																					Fat clay CH	
14	46.4																					Fat clay CH	
15	46.8																					Clayey sand SC	
16	48.6						8	13	25	41	71	91	96	98	100		1.4	0.49	0.13	10.8	1.3	Silty sand SM-SW	
17	51.3						10	16	24	33	50	63	78	99	100		4.0	0.67	0.070	57.1	1.6	Silty gravelly sand SM-SW	
18	53.3																					Silty sand SM	
19	53.6																					Shale CH	
20	56.0																					Shale CH	
Hole	82-61																						
1	1.4																					Sandy clay CL	
2	6.0																					Sandy silt ML	
3	10.7																					Sandy clay CL	
4	15.8																					Sandy clay CL	
5	21.0																					Silty gravelly sand SM	
6	26.3						13	19	29	41	58	72	86	97	100							Silty gravelly sand SM	
7	31.1																					Shale CH	
8	33.4																					Silty sand SM	
9	35.8																					Shale CH	
10	38.3																					Sandstone SC	

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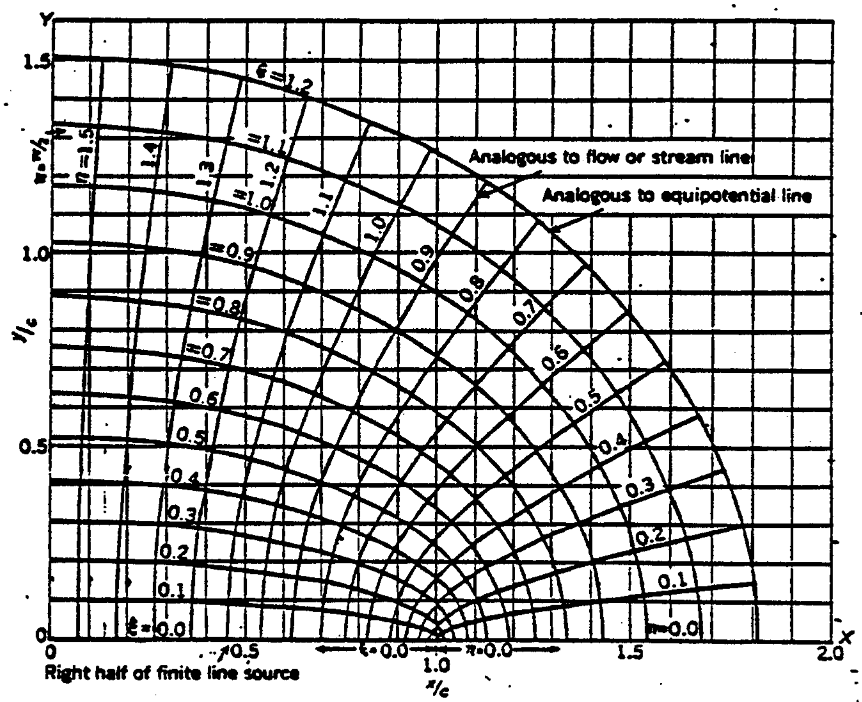
Table C-3

DRAWDOWN ANALYSIS USING

MUSKAT EQUATION

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA - NW BOUNDARY		SHEET NO.	OF
ITEM MUSKAT EQUATION		BY	DATE
		CHKD. BY	DATE



—Diagram for effecting the transformation from rectangular coordinates to a form of hyperbolic coordinates.

EQUATION

$$S = \frac{264Q}{T} \log_{10}\left[\frac{\cosh(\mathcal{E}+\mathcal{E}_o)-\cos(n-n_o)}{\cosh(\mathcal{E}-\mathcal{E}_o)-\cos(n-n_o)} \times \frac{\cosh(\mathcal{E}+\mathcal{E}_o)-\cos(n+n_o)}{\cosh(\mathcal{E}-\mathcal{E}_o)-\cos(n+n_o)}\right]$$

All Calculations were performed with a programmable TI-59 programmed to solve the above equation by entering $\mathcal{E}$, $\mathcal{E}_o$, n, n_o, Q, and T

Q = 100 gpm

T = 160,000 gpd (Average)

The above diagram was enlarged by computer allowing values for $\mathcal{E}$ and n to be read to the nearest .001.

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1 OCT 72

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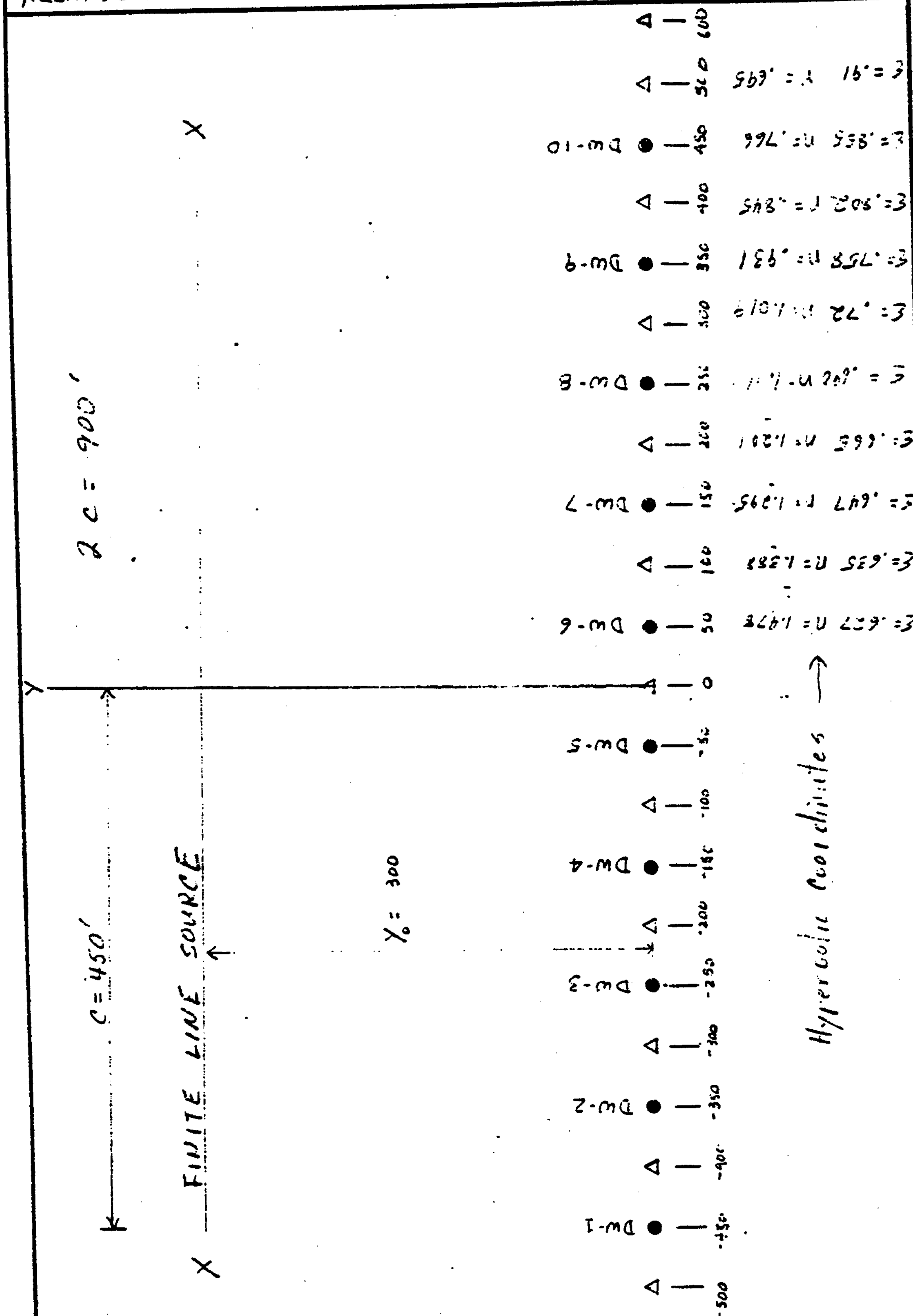
OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT FMA - NW Boundary	SHEET NO.	OF
ITEM	BY	DATE
RELATIVE POSITIONS FINITE LINE SOURCE + WELLS	CHKD. BY	DATE



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1 OCT 72

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OMAHA DISTRICT **COMPUTATION SHEET** CORPS OF ENGINEERS

PROJECT [illegible] Boundary | SHEET NO. OF

ITEM Hyperbolic Coordinates from Diagram | BY | DATE | CHKD. BY | DATE

$$Y/C = \frac{300}{450} = .666 \text{ (Always)}$$

$\frac{X}{C}$	N	E
$\frac{X_0}{C} = \frac{0}{450} = 0$		
$\frac{X_{50}}{C} = \frac{50}{450} = .111$	1.478	.627
$\frac{X_{100}}{C} = \frac{100}{450} = .222$	1.368	.633
$\frac{X_{150}}{C} = \frac{150}{450} = .333$	1.295	.647
$\frac{X_{200}}{C} = \frac{200}{450} = .444$	1.201	.665
$\frac{X_{250}}{C} = \frac{250}{450} = .555$	1.11	.690
$\frac{X_{300}}{C} = 300/450 = .666$	1.019	.720
$\frac{X_{350}}{C} = 350/450 = .777$	.931	.758
$\frac{X_{400}}{C} = \frac{400}{450} = .888$	.845	.802
$\frac{X_{450}}{C} = \frac{450}{450} = 1.00$	.766	.855
$\frac{X_{500}}{C} = \frac{500}{450} = 1.11$	.695	.910
$\frac{X_{600}}{C} = \frac{600}{450} = 1.333$	.574	1.037

OMAHA DISTRICT — COMPUTATION SHEET — CORPS OF ENGINEERS

PROJECT	SHEET NO.	OF
ITEM DRAWDOWN VS DISTANCE	BY	DATE
	CHKD. BY	DATE

DW-6

$\varepsilon_o = .627$
$n_o = 1.478$

S @ 50 = .415
$\varepsilon = .635$
$n = 1.388$

S @ 100' = .316
$\varepsilon = .647$
$n = 1.295$

S @ 200' = .227
$\varepsilon = .69$
$n = 1.11$

S @ 300' = .186
$\varepsilon = .758$
$n = .931$

S @ 400' = .167
$\varepsilon = .855$
$n = .766$

S @ 500' = .16
$\varepsilon = 1.037$
$n = .574$

DW-7

$\varepsilon_o = .647$
$n_o = 1.295$

S @ 50' = .417
$\varepsilon = .665$
$n = 1.251$

S @ 100' = .325
$\varepsilon = .690$
$n = 1.11$

S @ 200' = .242
$\varepsilon = .758$
$n = .931$

S @ 300' = .207
$\varepsilon = .855$
$n = .766$

S @ 350' = .198
$\varepsilon = .91$
$n = .695$

(-) direction

S @ 50' = .413
$\varepsilon = .635$
$n = 1.389$

S @ 100' = .316
$\varepsilon = .627$
$n = 1.478$

MRO FORM 1550
1 OCT 72

OMAHA DISTRICT | COMPUTATION SHEET | CORPS OF ENGINEERS

PROJECT	SHEET NO. OF	
ITEM DRAWDOWN VS DISTANCE	BY	DATE
	CHKD. BY	DATE

DW-8

$\varepsilon_{o1} = .69$

$n_o = 1.11$

s @ 50' = .438

$\varepsilon = .72$

$n = 1.019$

s @ 100' = .348

$\varepsilon = .758$

$n = .931$

s @ 250' = .253

$\varepsilon = .91$

$n = .695$

(–) direction

s @ 50' = .428

$\varepsilon = .665$

$n = 1.201$

s @ 100' = .325

$\varepsilon = .647$

$n = 1.295$

s @ 200' = .227

$\varepsilon = .627$

$n = 1.478$

DW-9

$\varepsilon_o = .758$

$n_o = .931$

s @ 50 = .471

$\varepsilon = .802$

$n = .845$

s @ 100 = .375

$\varepsilon = .855$

$n = .766$

s @ 150 = .342

$\varepsilon = .91$

$n = .695$

(–) direction

s @ 50' = .453

$\varepsilon = .72$

$n = 1.019$

s @ 100 = .348

$\varepsilon = .69$

$n = 1.11$

s @ 200 = .242

$\varepsilon = .647$

$n = 1.295$

s @ 300 = .186

$\varepsilon = .627$

$n = 1.478$

OMAHA DISTRICT | COMPUTATION SHEET | CORPS OF ENGINEERS

PROJECT	SHEET NO. OF	
ITEM DRAWDOWN VS DISTANCE	BY	DATE
	CHKD. BY	DATE

DW-10

$\mathcal{E}_0 = .855$
$n_0 = .766$

s @ 50' = .529
$\mathcal{E} = .91$
$n = .695$

(−) direction

s @ 50' = .495
$\mathcal{E} = .802$
$n = .845$

s @ 150' = .318
$\mathcal{E} = .72$
$n = 1.019$

s @ 250' = .235
$\mathcal{E} = .665$
$n = 1.201$

s @ 350' = .185
$\mathcal{E} = .635$
$n = 1.388$

s @ 400 = .167
$\mathcal{E} = .627$
$n = 1.479$

NOTES:

1) Drawdown beyond the Y-axis in the negative direction was calculated using the infinite line source equation $s = \frac{264Q}{T} \log_{10} \frac{r_i^2}{r_r^2}$ resulting in conservative drawdown at the ends of the discharge line. Calculated drawdowns with a infinite line source are less than calculated drawdowns with a finite line source.

2) Calculated drawdowns at the slurry wall end of the discharge line are conservative. Transmissivity decreases at this end as the saturated thickness decreases. Actual drawdowns will most likely be greater than the calculated drawdown

r_i=the distance from the image well to the point for which the drawdown is desired,
r_r=the distance from the real well to the point for which the drawdown is desired.

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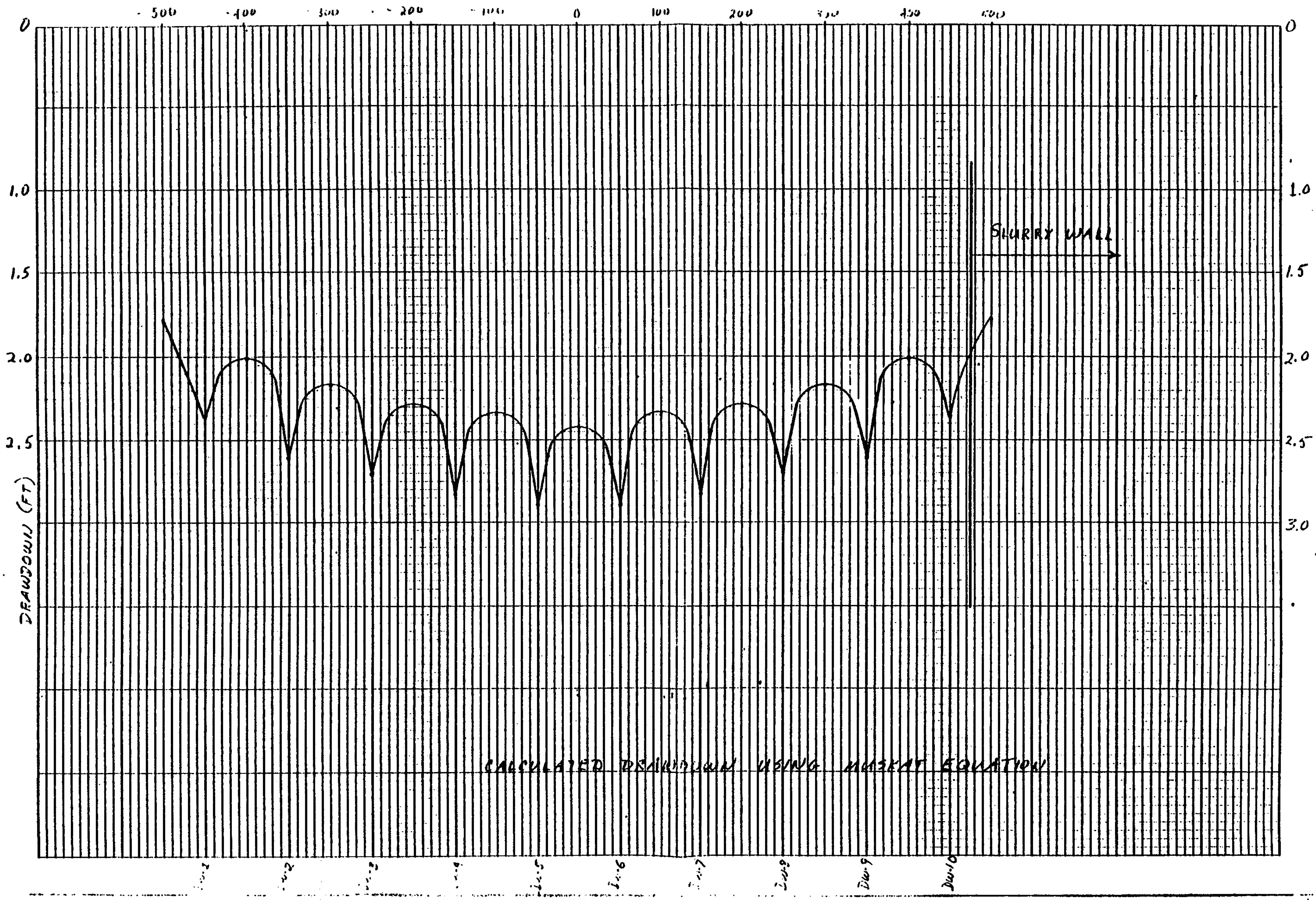

K+E 10 X 10 TO THE INCH 47 0700

CUTOFF WALL HYDRAULIC ANALYSIS

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA - NW Boundary		SHEET NO.	OF
ITEM Cutoff Wall Hydraulic Analysis		BY DJP	DATE
		CHKD. BY	DATE

Computer modeling indicates there will be a hydraulic gradient sloping northwest across the cutoff wall. The head difference varies from 0-feet @ the southwest end to over 5-feet @ the northeast end. The average head difference across the slurry cutoff wall is approximately 2.75 feet.

1. Hydraulic Gradient across cutoff (I) = approx 1 ft/ft
2. Permeability (K) of cutoff wall = .00028 ft/day (10^{-7} cm/sec)
3. Area (A) = 1425 × 50 = 71,250 ft^2
4. Flow (Q) = K I A

$Q = .00028 \times 1 \times 71,250 = 19.95$ Ft/day or 0.1 gpm

COMPUTER MODEL

A finite-difference computer model was used to simulate ground-water flow under various aquifer and pumping characteristics. A total of 10 simulations were run. Due to grid size limitations in the model, well and slurry wall locations could only approximate actual locations. In all simulations a line of recharge wells was located approximately 375 feet from the northwest boundary of RMA. The discharge well line and the slurry wall were located 550 feet from the recharge well line. Additional discharge wells were placed 100 feet behind the slurry wall (upgradient in terms of ground-water flow). For convenience, recharge wells will be numbered RW1 through RW16, from south to north. Discharge wells will be numbered DW1 through DW15 or DW16. The number of discharge wells will vary, depending on the simulation. Recharge wells were spaced at 100-foot intervals, except for those located downgradient of the slurry wall, which were spaced at 200-foot intervals (RW12 through RW16). Discharge wells were spaced at 100-foot intervals, except for those located upgradient of the slurry wall. Those wells upgradient of the slurry wall (DW12 through DW16) had variable spacings of 200, 30C, 200, and 300 feet when 4 wells were used, and were evenly spaced at 200 feet for simulations where 5 wells were used. Each of the simulations will be discussed in the following paragraphs.

<u>Simulation 1</u>: This simulation was run as an initial test of the model under pumping conditions after running a steady state, non-pumping calibration run. No slurry wall was simulated. The four discharge wells upgradient of the proposed slurry wall location were pumped at 25 gpm. Five recharge wells were located downgradient of the proposed slurry wall, with each well injecting 20 gpm. All other wells were pumping 100 gpm. The total system pumpage was 1,200 gpm. Gradient reversal was accomplished

in the area south of the proposed slurry wall, but was not accomplished in the area where the slurry wall would be built. This run reinforced the need for a slurry wall to create an effective system.

Simulation 2: This run attempted to simulate the slurry wall by specifying zero aquifer thickness at the proposed location. Results from this simulation were deemed unreliable after looking at the program code, because a saturated thickness, hence a transmissivity, could still be calculated at the slurry wall.

Simulation 3: A new data matrix was set up for this simulation, specifying a permeability of 3.3×10^{-10} ft/sec for the slurry wall. The permeability for the remainder of the aquifer was set at .0165 ft/sec (1400 ft/day). The pumping rates were the same as the first two simulations, with a pumping period of 30 days. The simulated slurry wall was 1,300 feet long. Gradient reversal was accomplished in the main well section of the system (those wells pumping 100 gpm), but was not successful in the area near the slurry wall. Downgradient of the slurry wall ground water still flows out of the system to the north. Locations upgradient of the slurry wall show a head build-up of up to 3 feet, with a head drop across the slurry wall of approximately 5 feet on the average.

Simulation 4: For this simulation a fifth well was added upgradient of the slurry wall to reduce the head build-up. Spacing between each well upgradient of the wall was set at 200 feet, and each well pumped 20 gpm. The total system pumpage was 1,200 gpm. Using a pumping period of 180 days, steady state was reached after 34 days. Little if any change was noticed between this run and Simulation 3, including the head build-up behind the slurry wall.

Simulation 5: Simulation 5 maintained the same pumping rates as Simulation 4: five wells upgradient and downgradient of the slurry wall pumping 20 gpm and all other wells pumping 100 gpm. The permeability was changed from .0165 ft/sec to .00825 ft/sec for the area north of RW12 and DW12 (approximately one-half the model) to more accurately represent actual properties of the aquifer. This representation was used in all future simulations. The results show gradient reversal between DW and RW wells 1 through 12. Ground water appears to stagnate near well RW14. South of RW14 there is a slight component of flow toward the slurry wall. The flow along the recharge well side of the slurry wall is toward the north, while on the discharge well side the flow is toward the south. In this simulation the head drop across the slurry wall decreased from an average of 5 feet to an average of 3 feet, with a maximum head loss of 6 feet at the north end of the slurry wall. The change in head drop across the wall was a direct result of changing the permeability on that half of the model.

Simulation 6: For Simulation 6 there were 16 discharge wells and 16 recharge wells. Discharge wells DW1 and DW2 were pumped at 150 gpm; DW3 through DW11 were pumped at 100 gpm; DW12 was pumped at 20 gpm; and DW13 through DW16 were pumped at 25 gpm. Recharge wells RW1 through RW11 were pumped at 100 gpm; RW12 and RW13 were pumped at 20 gpm; and RW14 through RW16 were pumped at 60 gpm. The total system pumpage was 1,320 gpm. The length of the slurry wall was 1,300 feet. The gradient was reversed between RW and DW wells 1 through 11. In addition to reversing the gradient between those wells, a gradient was induced so that flow along both sides of the slurry wall was toward the south, thus preventing any ground water from escaping the system to the north. This would increase the amount of recirculation in the system. Because of the high amount of

recharge in wells RW14 through RW16, and the increased discharge in wells DW13 through DW16, the head drop through the slurry wall was reduced to less than 1 foot.

Simulation 7: The number of wells upgradient of the 1,300-foot-long slurry wall was reduced to four for this run, making a total of 15 discharge wells. Each of the four wells pumped 25 gpm. Wells RW14 through RW16 injected 53 gpm, and all other wells, recharge and discharge, pumped the same as described for Simulation 6. The total system pumpage was 1,300 gpm. Results were the same as for Simulation 6, except that a stagnation point developed in the ground-water flow near wells RW15 and RW16. South of these wells ground water appears to flow along the slurry wall toward the discharge wells. This simulation reached steady state after 79 days of pumping, compared to 52 days for Simulation 6.

Simulation 8: In this simulation the slurry wall was extended 100 feet, to a total length of 1,400 feet. Well DW11, originally at the south end of the slurry wall, was moved 100 feet behind (upgradient) of the wall. The pumping rate of DW11 was reduced from 100 gpm to 25 gpm. Wells DW12 through DW15 were also pumped at 25 gpm; DW1 and DW2 were pumped at 150 gpm. Recharge wells RW12 and RW13 injected 20 gpm, while RW14 through RW16 injected 28 gpm. All other wells were pumped at 100 gpm, for a total system pumpage of 1,225 gpm. The stagnation point for ground-water flow moved south for this simulation, with ground water flowing north along all but the southernmost 300 feet of the slurry wall. This is attributed to the decreased amount of water injected in wells RW14 through RW16 and the decreased system pumpage. Gradient reversal was not affected in the area of contaminant concentration, so the system is considered effective. A maximum head build-up of 1 foot is still

apparent upgradient of the slurry wall, indicating the wells are not pumping 100% of flux in that area. Steady state for this simulation was reached in 34 days. This simulation is contoured on Plate 1.

Simulation 9: Pumping rates of wells upgradient of the slurry wall were increased to 30 gpm each in an attempt to reduce the head build-up behind the wall. The additional water was distributed to recharge wells RW15 and RW16, increasing the recharge rate from 28 gpm to 40 gpm for each well. All other conditions remained the same as Simulation 8. Steady state was reached in 34 days. Head build-up behind the slurry wall was reduced to a maximum of .5 foot. Ground water along the slurry wall was essentially stagnant, with the only component of flow being toward the slurry wall from the recharge wells.

Simulation 10: This simulation was run to test the designed system start-up conditions. Five wells (DW11-DW15) were located upgradient of the slurry wall, each pumping 25 gpm. Six wells (RW11-RW16) were located downgradient of the slurry wall, with five of the wells injecting 20 gpm and the other well injecting 25 gpm. All remaining recharge and discharge wells pumped 100 gpm. The pumping period was 180 days, with steady state being reached after 52 days of pumping. Gradient reversal had been established as early as nine days into the pumping period. Upgradient of the slurry wall, a maximum head build-up of 1.3 feet occurred, with a maximum drawdown of 2.3 feet immediately downgradient of the slurry wall. The head drop across the wall ranged from a maximum of 6.4 feet at the north end to -0.3 foot at the south end. Flow on the downgradient side of the slurry wall was toward the north, with a small component of flow toward the slurry wall. This simulation is contoured on Plate 2.

Of the 10 simulations that were run, the first two were considered test runs and the results do not apply to system operation simulation. The remaining eight simulations suggest that any of the simulated systems will work to create a hydraulic barrier to contaminant flow. The model, however, is only a guide. Monitoring of the installed system will be the only true method of determining whether a hydraulic barrier is actually established.

The final three simulations more accurately represent conditions in the field than Simulations 3 through 7. Results from Simulations 8, 9, and 10 are presented at the end of this appendix. If the designed start-up system (Simulation 10) does not create adequate results, Simulations 8 and 9 suggest that increasing the pumping rate in the first two discharge wells and directing the increased flow to the last two or three recharge wells, will create a workable system.

SIMULATION 8

PUMPING PERIOD NO. 19 180.00 DAYS

NUMBER OF TIME STEPS= 12

DELT IN HOURS = 11.185

MULTIPLIER FOR DELT = 1.500

31 WELLS

	I	J	PUMPING RATE	WELL RADIUS
RW16	21	6	0.06	0.50
RW15	23	5	0.06	0.50
RW14	25	5	0.06	0.50
RW13	27	5	0.05	0.50
RW12	29	5	0.05	0.50
RW11	31	5	0.22	0.50
RW10	32	5	0.22	0.50
RW9	33	5	0.22	0.50
RW8	34	5	0.22	0.50
RW7	35	5	0.22	0.50
RW6	36	5	0.22	0.50
RW5	37	5	0.22	0.50
RW4	38	5	0.22	0.50
RW3	39	5	0.22	0.50
RW2	40	5	0.22	0.50
RW1	41	5	0.22	0.50
DW15	21	9	-0.06	0.50
DW14	24	9	-0.06	0.50
DW13	25	9	-0.06	0.50
DW12	29	9	-0.06	0.50
DW11	31	9	-0.06	0.50
DW10	32	8	-0.22	0.50
DW9	33	8	-0.22	0.50
DW8	34	8	-0.22	0.50
DW7	35	8	-0.22	0.50
DW6	36	8	-0.22	0.50
DW5	37	8	-0.22	0.50
DW4	38	8	-0.22	0.50
DW3	39	5	-0.22	0.50
DW2	40	8	-0.33	0.50
DW1	41	8	-0.33	0.50

```
 ---------------------------------------------------------
 I              TIME STEP NUMBER =        8              I
 ---------------------------------------------------------

      SIZE OF TIME STEP IN SECONDS=    1031952.62

           TOTAL SIMULATION TIME IN SECONDS=     2975061.00
                                    MINUTES=       49584.34
                                      HOURS=         826.41
                                       DAYS=          34.43
                                      YEARS=           0.09

 DURATION OF CURRENT PUMPING PERIOD IN DAYS=          34.43
                                      YEARS=           0.09

CUMULATIVE MASS BALANCE:              L**3          RATES FOR THIS TIME STEP:              L**3/T
------------------------                            ------------------------

      SOURCES:                                                   STORAGE =           -0.0023
      --------                                                  RECHARGE =            0.0
              STORAGE =            -7247.28                CONSTANT FLUX =            2.6990
             RECHARGE =                0.0                       PUMPING =           -2.7080
        CONSTANT FLUX =          8029676.00           EVAPOTRANSPIRATION =            0.0
        CONSTANT HEAD =         12412357.0                 CONSTANT HEAD:
              LEAKAGE =                0.0                            IN =            4.1937
        TOTAL SOURCES =         20434784.0                           OUT =           -4.1685
                                                                 LEAKAGE:
      DISCHARGES:                          FROM PREVIOUS PUMPING PERIOD =            0.0
      -----------                                                  TOTAL =            0.0
   EVAPOTRANSPIRATION =                0.0
        CONSTANT HEAD =         12446587.0                  SUM OF RATES =            0.0139
     QUANTITY PUMPED =           8056452.00
              LEAKAGE =                0.0
      TOTAL DISCHARGE =         20503024.0

    DISCHARGE-SOURCES =            68240.00
   PER CENT DIFFERENCE =               0.33

MAXIMUM HEAD CHANGE FOR EACH ITERATION:
---------------------------------------

      0.0200

MAXIMUM CHANGE IN HEAD FOR THIS TIME STEP =      0.020
-----------------------------------------------------

TIME STEP :  1  2  3  4  5  6  7  8
----------

ITERATIONS: 15 10 10 10 11 10 10  0
----------
```

HEAD MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	83.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	83.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	83.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	83.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	112.21
9	0.0	83.00	0.0	0.0	0.0	0.0	151.12	151.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.15	108.70	109.64	111.43
10	0.0	83.00	0.0	0.0	0.0	0.0	151.12	151.12	0.0	0.0	0.0	0.0	0.0	0.0	106.63	107.11	107.73	108.32	109.15	110.67
11	0.0	83.00	0.0	0.0	0.0	0.0	151.12	0.0	0.0	0.0	0.0	104.65	105.13	105.60	106.20	106.79	107.40	107.97	108.57	109.44
12	0.0	83.10	0.0	0.0	0.0	0.0	151.12	0.0	0.0	0.0	0.0	104.16	104.68	105.25	105.87	106.49	107.10	107.65	108.15	108.73
13	0.0	83.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	102.81	103.52	104.02	104.68	105.43	106.17	106.83	107.37	107.83	108.31
14	0.0	83.30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	101.47	102.10	102.72	103.27	103.97	104.87	105.85	106.63	107.21	107.65	108.08
15	0.0	83.40	0.0	0.0	0.0	0.0	0.0	0.0	100.73	100.76	101.34	101.93	102.48	103.15	104.07	104.97	0.0	0.0	0.0	0.0
16	0.0	83.50	0.0	0.0	0.0	0.0	0.0	101.03	0.0	99.92	100.39	100.99	101.62	102.20	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	83.60	87.20	0.0	0.0	0.0	0.0	0.0	0.0	98.96	99.43	100.04	100.88	101.50	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	83.70	87.30	89.72	0.0	0.0	0.0	[illegible]	97.68	98.01	98.34	98.58	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	83.90	87.34	89.75	91.19	91.48	91.58	[illegible]	97.19	97.38	97.45	97.35	97.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0

20	0.0	83.90	87.38	89.81	91.30	91.53	91.59	94.07	96.29	96.55	96.70	96.72	96.60	96.37	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	84.00	87.41	89.87	91.47	91.57	91.61	93.91	95.36	95.81	96.07	96.19	96.19	96.10	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	84.20	87.44	89.97	91.51	91.62	91.64	93.78	95.24	95.46	95.66	95.80	95.87	95.92	95.98	0.0	0.0	0.0	0.0	0.0
23	0.0	84.40	87.49	90.11	91.67	91.67	91.68	93.65	94.94	95.14	95.34	95.51	95.67	95.83	96.05	96.38	96.83	0.0	0.0	0.0
24	0.0	84.60	87.57	90.26	91.68	91.72	91.71	93.50	94.34	94.75	95.05	95.26	95.48	95.74	96.11	96.61	97.33	98.42	0.0	0.0
25	0.0	84.80	87.70	90.36	91.80	91.77	91.76	93.35	93.94	94.35	94.72	95.00	95.26	95.59	96.07	96.78	97.76	99.61	103.38	107.93
26	0.0	85.00	87.91	90.48	91.89	91.84	91.82	93.17	92.76	93.68	94.19	94.58	94.94	95.32	95.86	96.66	97.85	99.78	103.90	108.76
27	0.0	85.20	88.15	90.65	92.14	91.93	91.87	93.03	92.61	93.09	93.58	93.98	94.38	94.80	95.36	96.17	97.42	99.74	104.32	109.51
28	0.0	85.40	88.36	90.80	92.24	92.01	91.89	92.95	92.07	92.41	92.85	93.26	93.63	94.04	94.53	95.22	96.31	0.0	0.0	0.0
29	0.0	85.60	88.50	90.90	92.40	92.05	91.87	92.87	91.59	91.95	92.33	92.69	93.03	93.39	93.78	94.27	0.0	0.0	0.0	0.0
30	0.0	85.80	88.60	90.96	92.54	92.06	91.79	92.80	91.46	91.76	92.08	92.41	92.70	92.97	93.20	93.41	0.0	0.0	0.0	0.0
31	0.0	86.00	88.70	91.03	92.84	92.04	91.65	92.74	91.15	91.52	91.85	92.15	92.42	92.63	92.76	92.74	0.0	0.0	0.0	0.0
32	0.0	86.20	88.80	91.08	92.88	92.00	91.42	90.75	91.08	91.39	91.68	91.95	92.20	92.39	92.52	92.58	92.56	0.0	0.0	0.0
33	0.0	86.40	88.90	91.12	92.84	91.98	91.36	90.83	91.08	91.36	91.62	91.85	92.07	92.27	92.42	92.51	92.55	0.0	0.0	0.0
34	0.0	86.60	88.99	91.16	92.79	91.96	91.36	90.85	91.12	91.39	91.64	91.85	92.05	92.24	92.40	92.51	92.57	92.59	0.0	0.0
35	0.0	86.80	89.09	91.19	92.73	91.95	91.37	90.91	91.18	91.45	91.69	91.91	92.10	92.28	92.44	92.57	92.65	92.71	0.0	0.0
36	0.0	87.00	89.18	91.20	92.67	91.94	91.40	90.97	91.26	91.53	91.78	92.01	92.20	92.38	92.55	92.69	92.78	92.91	0.0	0.0
37	0.0	87.10	89.27	91.22	92.62	91.95	91.44	91.04	91.34	91.63	91.89	92.13	92.33	92.52	92.69	92.84	92.97	93.10	0.0	0.0
38	0.0	87.20	89.35	91.22	92.57	91.97	91.50	91.12	91.44	91.75	92.03	92.27	92.48	92.68	92.86	93.02	93.17	93.28	93.43	0.0
39	0.0	87.30	89.42	91.23	92.52	92.00	91.57	91.19	91.56	91.89	92.18	92.43	92.65	92.85	93.03	93.20	93.34	93.46	93.59	0.0

40	0.0	87.40	89.49	91.22	92.47	92.05	91.68	91.26	91.72	92.07	92.37	92.62	92.83	93.03	93.20	93.37	93.51	93.63	93.75	94.00
41	0.0	87.50	89.56	91.22	92.37	92.11	91.86	91.54	91.97	92.30	92.58	92.82	93.03	93.21	93.39	93.54	93.68	93.81	93.92	94.15
42	0.0	87.60	89.63	91.21	92.20	92.18	92.12	92.11	92.33	92.58	92.82	93.04	93.24	93.41	93.58	93.73	93.87	94.00	94.13	94.34
43	0.0	87.70	89.70	91.22	92.12	92.27	92.35	92.46	92.63	92.84	93.06	93.26	93.45	93.62	93.78	93.93	94.07	94.21	94.34	94.53
44	0.0	87.80	89.77	91.23	92.09	92.37	92.55	92.72	92.89	93.09	93.29	93.49	93.67	93.84	94.00	94.14	94.29	94.42	94.57	94.77
45	0.0	87.90	89.85	91.26	92.11	92.43	92.73	92.94	93.13	93.33	93.53	93.72	93.89	94.06	94.21	94.36	94.51	94.66	94.82	95.06
46	0.0	88.00	89.94	91.31	92.14	92.59	92.91	93.15	93.36	93.57	93.77	93.96	94.13	94.29	94.44	94.59	94.75	94.91	95.08	95.34
47	0.0	88.20	90.05	91.38	92.22	92.75	93.14	93.42	93.65	93.87	94.07	94.25	94.42	94.58	94.74	94.89	95.06	95.23	95.41	95.68
48	0.0	88.50	90.25	91.53	92.38	93.02	93.51	93.84	94.08	94.30	94.49	94.67	94.83	94.99	95.16	95.32	95.49	95.66	95.85	96.13
49	0.0	89.00	90.60	91.83	92.79	93.62	94.17	94.48	94.70	94.91	95.08	95.25	95.41	95.57	95.74	95.90	96.07	96.25	96.45	96.71
50	0.0	90.00	91.33	92.66	93.76	94.54	95.03	95.36	95.59	95.77	95.94	96.12	96.28	96.43	96.59	96.75	96.93	97.11	97.31	97.60
51	0.0	91.00	92.59	94.15	95.16	95.77	96.18	96.46	96.68	96.93	97.18	97.38	97.54	97.70	97.87	98.04	98.22	98.42	98.65	98.98
52	0.0	92.00	94.00	96.00	97.00	97.50	97.70	98.00	98.20	98.50	98.80	99.00	99.30	99.50	99.70	100.00	99.60	99.85	100.13	100.53
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0														
2	0.0	0.0	0.0	140.01	139.00	0.0														
3	0.0	0.0	0.0	142.43	144.00	0.0														
4	0.0	0.0	0.0	142.89	146.00	0.0														
5	0.0	0.0	135.80	141.64	147.00	0.0														
6	0.0	0.0	134.57	140.72	148.00	0.0														
7	0.0	0.0	133.77	140.33	149.00	0.0														
8	115.06	121.28	132.87	140.14	149.60	0.0														
9	114.72	120.82	132.22	140.13	148.60	0.0														

DRAWDOWN

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	-0.00	0.0	0.0														
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	-0.00	0.0	0.0														
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	-0.00	0.0	0.0														
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	-0.01	-0.00	0.0	0.0														
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	-0.01	-0.00	0.0	0.0														
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	-0.01	-0.00	0.0	0.0														
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02
	0.01	-0.01	-0.01	-0.00	0.0	0.0														
9	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.03	-0.02	-0.00	0.02
	0.01	-0.01	-0.01	-0.00	0.0	0.0														
10	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	-0.06	-0.05	-0.04	-0.02	-0.01	0.01
	0.01	-0.01	-0.01	-0.00	0.0	0.0														
11	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	-0.10	-0.09	-0.08	-0.07	-0.05	-0.04	-0.03	-0.02	-0.01
	0.0	-0.00	0.0	-0.00	0.0	0.0														
12	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	-0.13	-0.12	-0.10	-0.09	-0.08	-0.07	-0.07	-0.06	-0.05
	0.0	0.0	0.0	0.0	0.0	0.0														
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.16	-0.14	-0.12	-0.10	-0.08	-0.07	-0.05	-0.04	-0.04	-0.03
	0.0	0.0	0.0	0.0	0.0	0.0														
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.18	-0.19	-0.17	-0.15	-0.13	-0.10	-0.08	-0.06	-0.05	-0.04	-0.03
	0.0	0.0	0.0	0.0	0.0	0.0														
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.22	-0.26	-0.24	-0.21	-0.19	-0.16	-0.12	-0.09	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.41	-0.33	-0.28	-0.24	-0.19	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														
17	0.0	0.0	-0.23	0.0	0.0	0.0	0.0	0.0	0.0	-0.55	-0.44	-0.36	-0.29	-0.24	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														
18	0.0	0.0	-0.24	-0.33	0.0	0.0	0.0	-0.00	-0.87	-0.70	-0.59	-0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														
19	0.0	0.0	-0.24	-0.33	-0.26	0.66	1.70	[illegible]	-0.94	-0.75	-0.64	-0.59	-0.55	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														

20	0.0 0.0	0.0 0.0	-0.24 0.0	-0.34 0.0	-0.27 0.0	0.64 0.0	1.54	0.00	-1.12	-0.77	-0.64	-0.57	-0.53	-0.48	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0 0.0	0.0 0.0	-0.25 0.0	-0.35 0.0	-0.38 0.0	0.64 0.0	1.53	0.01	-0.82	-0.71	-0.61	-0.53	-0.48	-0.44	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0 0.0	0.0 0.0	-0.25 0.0	-0.37 0.0	-0.36 0.0	0.61 0.0	1.47	0.01	-0.96	-0.70	-0.55	-0.47	-0.41	-0.38	-0.37	0.0	0.0	0.0	0.0	0.0
23	0.0 0.0	0.0 0.0	-0.26 0.0	-0.39 0.0	-0.46 0.0	0.52 0.0	1.33	0.01	-0.81	-0.57	-0.44	-0.37	-0.33	-0.34	-0.38	-0.50	-0.65	0.0	0.0	0.0
24	0.0 0.0	0.0 0.0	-0.27 0.0	-0.42 0.0	-0.43 0.0	0.42 0.0	1.17	0.01	-0.35	-0.32	-0.27	-0.23	-0.22	-0.27	-0.38	-0.57	-0.86	-1.06	0.0	0.0
25	0.0 -1.55	0.0 0.0	-0.30 0.0	-0.45 0.0	-0.53 0.0	0.31 0.0	0.99	0.00	-0.07	-0.03	-0.05	-0.06	-0.08	-0.16	-0.32	-0.60	-0.98	-1.32	-1.19	-1.14
26	0.0 -1.60	0.0 0.0	-0.33 0.0	-0.50 0.0	-0.58 0.0	0.24 0.0	0.85	0.01	0.90	0.44	0.30	0.22	0.14	0.03	-0.17	-0.50	-1.02	-1.52	-1.04	-0.82
27	0.0 -2.05	0.0 -1.81	-0.37 0.0	-0.59 0.0	-0.79 0.0	0.16 0.0	0.75	0.01	0.83	0.80	0.70	0.61	0.50	0.37	0.14	-0.24	-0.89	-1.53	-0.88	-0.78
28	0.0 -2.56	0.0 -1.75	-0.41 -1.07	-0.68 0.0	-0.84 0.0	0.09 0.0	0.69	0.01	1.23	1.24	1.16	1.07	0.97	0.84	0.65	0.31	-0.30	0.0	0.0	0.0
29	0.0 -2.66	0.0 -1.61	-0.40 -1.02	-0.72 -0.09	-0.97 0.0	0.04 0.0	0.67	0.01	1.68	1.55	1.47	1.38	1.30	1.18	1.02	0.79	95.54	0.0	0.0	0.0
30	0.0 -1.76	0.0 -1.44	-0.36 -0.95	-0.73 -0.08	-1.06 0.0	0.06 0.0	0.73	0.01	1.63	1.62	1.56	1.48	1.40	1.32	1.25	1.17	0.0	0.0	0.0	0.0
31	0.0 -0.93	0.0 -1.27	-0.34 -0.88	-0.73 -0.08	-1.28 0.0	0.11 0.0	0.86	0.04	1.84	1.73	1.65	1.58	1.51	1.45	1.43	1.48	94.15	0.0	0.0	0.0
32	0.0 -0.91	0.0 -1.09	-0.32 -0.85	-0.72 -0.08	-1.26 0.0	0.16 0.0	1.09	2.01	1.89	1.79	1.72	1.65	1.59	1.54	1.51	1.51	1.51	94.0	0.0	0.0
33	0.0 -0.92	0.0 -0.98	-0.30 -0.81	-0.70 0.0	-1.18 0.0	0.21 0.0	1.16	1.97	1.89	1.81	1.74	1.68	1.63	1.58	1.54	1.52	1.51	94.07	0.0	0.0
34	0.0 -0.92	0.0 -0.92	-0.29 -0.77	-0.66 0.0	-1.11 0.0	0.25 0.0	1.20	1.95	1.87	1.80	1.73	1.68	1.63	1.58	1.54	1.51	1.49	1.49	94.09	0.0
35	0.0 0.0	0.0 -0.89	-0.27 -0.74	-0.62 -0.22	-1.04 0.0	0.29 0.0	1.22	1.93	1.86	1.78	1.71	1.66	1.61	1.56	1.51	1.47	1.46	1.42	0.0	0.0
36	0.0 0.0	0.0 0.0	-0.26 -0.69	-0.58 -0.23	-0.97 0.0	0.33 0.0	1.24	1.92	1.84	1.76	1.68	1.62	1.57	1.52	1.47	1.42	1.40	1.33	0.0	0.0
37	0.0 0.0	0.0 0.0	-0.24 -0.64	-0.54 -0.24	-0.89 0.0	0.36 0.0	1.25	1.91	1.81	1.72	1.64	1.58	1.52	1.46	1.41	1.36	1.32	1.27	94.48	0.0
38	0.0 0.0	0.0 0.0	-0.23 -0.59	-0.49 -0.23	-0.81 0.0	0.39 0.0	1.25	1.90	1.79	1.68	1.60	1.52	1.46	1.40	1.35	1.30	1.26	1.22	1.16	0.0
39	0.0 0.0	0.0 0.0	-0.21 -0.56	-0.44 -0.23	-0.72 0.0	0.41 0.0	1.24	1.90	1.75	1.63	1.54	1.46	1.40	1.34	1.29	1.24	1.20	1.17	1.12	0.0

40	0.0	0.0	-0.18	-0.38	-0.61	0.43	1.22	1.93	1.69	1.55	1.46	1.38	1.33	1.28	1.23	1.19	1.16	1.12	1.10	1.02
	0.0	0.0	0.0	-0.23	-0.01	0.0														
41	0.0	0.0	-0.16	-0.31	-0.45	0.45	1.13	1.74	1.54	1.43	1.35	1.30	1.26	1.21	1.17	1.14	1.11	1.04	1.05	0.98
	0.0	0.0	0.0	-0.22	-0.01	0.0														
42	0.0	0.0	-0.14	-0.24	-0.20	0.47	0.97	1.27	1.30	1.27	1.24	1.21	1.18	1.14	1.11	1.08	1.06	1.03	1.00	0.95
	0.0	0.0	0.0	0.0	-0.01	0.0														
43	0.0	0.0	-0.11	-0.17	-0.04	0.47	0.84	1.04	1.11	1.13	1.13	1.11	1.09	1.07	1.05	1.03	1.00	0.98	0.96	0.92
	0.0	0.0	0.0	0.0	-0.00	0.0														
44	0.0	0.0	-0.09	-0.11	0.06	0.46	0.75	0.90	0.97	1.01	1.02	1.03	1.02	1.00	0.99	0.97	0.95	0.93	0.91	0.88
	0.76	0.0	0.0	0.0	-0.00	0.0														
45	0.0	0.0	-0.07	-0.06	0.13	0.45	0.68	0.80	0.87	0.92	0.94	0.94	0.94	0.94	0.93	0.91	0.90	0.88	0.86	0.82
	0.73	0.0	0.0	0.0	-0.00	0.0														
46	0.0	0.0	-0.06	-0.02	0.17	0.44	0.63	0.73	0.80	0.84	0.86	0.87	0.88	0.88	0.87	0.86	0.84	0.81	0.81	0.78
	0.71	0.49	0.09	0.0	0.0	0.0														
47	0.0	0.0	-0.04	0.01	0.20	0.42	0.58	0.67	0.72	0.76	0.78	0.79	0.80	0.80	0.80	0.79	0.78	0.76	0.75	0.72
	0.67	0.51	0.08	-0.04	0.0	0.0														
48	0.0	0.0	-0.02	0.05	0.21	0.40	0.53	0.59	0.64	0.67	0.69	0.70	0.71	0.71	0.71	0.70	0.69	0.68	0.67	0.65
	0.61	0.52	0.09	-0.06	0.0	0.0														
49	0.0	0.0	0.00	0.07	0.21	0.36	0.46	0.51	0.54	0.56	0.58	0.59	0.60	0.60	0.60	0.59	0.59	0.58	0.57	0.56
	0.53	0.49	0.21	0.0	0.0	0.0														
50	0.0	0.0	0.02	0.08	0.17	0.25	0.32	0.37	0.40	0.42	0.44	0.45	0.46	0.46	0.46	0.46	0.46	0.46	0.45	0.44
	0.41	0.35	0.19	0.11	0.0	0.0														
51	0.0	0.0	0.02	0.06	0.00	0.13	0.16	0.18	0.20	0.22	0.24	0.25	0.26	0.27	0.27	0.27	0.28	0.28	0.28	0.27
	0.26	0.23	0.16	0.09	0.0	0.0														
52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.04	0.05
	0.07	0.08	0.08	0.04	0.0	0.0														
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														

HEAD AND DRAWDOWN IN PUMPING WELLS

I	J	WELL RADIUS	HEAD	DRAWDOWN
21	5	0.50	92.07	-0.98
23	5	0.50	92.27	-1.06
25	5	0.50	92.16	-0.88
27	5	0.50	92.78	-1.43
29	5	0.50	92.68	-1.24
31	5	0.50	93.89	-2.33
32	5	0.50	93.50	-1.88
33	5	0.50	93.31	-1.65
34	5	0.50	93.24	-1.56
35	5	0.50	93.10	-1.49
36	5	0.50	93.12	-1.41

37	5	0.50	93.04	-1.32
38	5	0.50	93.00	-1.24
39	5	0.50	92.93	-1.13
40	5	0.50	92.90	-1.04
41	5	0.50	92.82	-0.90
21	9	0.50	94.85	-0.31
24	9	0.50	93.83	0.16
26	9	0.50	91.42	2.24
29	9	0.50	91.10	2.08
31	9	0.50	90.90	2.09
32	8	0.50	90.18	2.58
33	8	0.50	90.36	2.41
34	8	0.50	90.43	2.36
35	8	0.50	90.51	2.33
36	8	0.50	90.60	2.29
37	8	0.50	90.67	2.28
38	8	0.50	90.76	2.25
39	8	0.50	90.80	2.30
40	8	0.50	90.66	2.53
41	8	0.50	90.94	2.34

SIMULATION 9

PUMPING PERIOD NO. 1 180.00 DAYS

NUMBER OF TIME STEPS= 12

DELT IN HOURS = 11.185

MULTIPLIER FOR DELT = 1.500

31 WELLS

	I	J	PUMPING RATE	WELL RADIUS
RW16	21	5	0.09	0.50
RW15	23	5	0.09	0.50
RW14	25	5	0.06	0.50
RW13	27	5	0.05	0.50
RW12	29	5	0.05	0.50
RW11	31	5	0.22	0.50
RW10	32	5	0.22	0.50
RW9	33	5	0.22	0.50
RW8	34	5	0.22	0.50
RW7	35	5	0.22	0.50
RW6	36	5	0.22	0.50
RW5	37	5	0.22	0.50
RW4	38	5	0.22	0.50
RW3	39	5	0.22	0.50
RW2	40	5	0.22	0.50
RW1	41	5	0.22	0.50
DW15	21	9	-0.07	0.50
DW14	24	9	-0.07	0.50
DW13	26	9	-0.07	0.50
DW12	29	9	-0.07	0.50
DW11	31	9	-0.07	0.50
DW10	32	8	-0.22	0.50
DW9	33	8	-0.22	0.50
DW8	34	8	-0.22	0.50
DW7	35	8	-0.22	0.50
DW6	36	8	-0.22	0.50
DW5	37	8	-0.22	0.50
DW4	38	8	-0.22	0.50
DW3	39	8	-0.22	0.50
DW2	40	8	-0.33	0.50
DW1	41	8	-0.33	0.50

```
I                TIME STEP NUMBER =        8                I

     SIZE OF TIME STEP IN SECONDS=    1031952.62

          TOTAL SIMULATION TIME IN SECONDS=    2975061.00
                                   MINUTES=      49584.34
                                     HOURS=        826.41
                                      DAYS=         34.43
                                     YEARS=          0.09

DURATION OF CURRENT PUMPING PERIOD IN DAYS=         34.43
                                     YEARS=          0.09

CUMULATIVE MASS BALANCE*         L**3            RATES FOR THIS TIME STEP*              L**3/T

         SOURCES*                                                  STORAGE =            -0.0021
                                                                  RECHARGE =             0.0
               STORAGE =         11378.39                    CONSTANT FLUX =             2.7440
              RECHARGE =             0.0                           PUMPING =            -2.7630
         CONSTANT FLUX =       8163553.00               EVAPOTRANSPIRATION =             0.0
         CONSTANT HEAD =      12422958.0                     CONSTANT HEAD*
               LEAKAGE =             0.0                                IN =             4.1982
         TOTAL SOURCES =      20597888.0                               OUT =            -4.1797
                                                                  LEAKAGE*
         DISCHARGES*                        FROM PREVIOUS PUMPING PERIOD =             0.0
                                                                     TOTAL =             0.0
    EVAPOTRANSPIRATION =             0.0
         CONSTANT HEAD =      12478559.0                      SUM OF RATES =            -0.0026
      QUANTITY PUMPED =       8220081.00
               LEAKAGE =             0.0
       TOTAL DISCHARGE =      20698640.0

     DISCHARGE-SOURCES =        100752.00
   PER CENT DIFFERENCE =            0.49

MAXIMUM HEAD CHANGE FOR EACH ITERATION*

      0.0200

MAXIMUM CHANGE IN HEAD FOR THIS TIME STEP =     0.020

TIME STEP =  1  2  3  4  5  6  7  8

ITERATIONS= 15 10 10 11 11 10 10  0
```

HEAD MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	83.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	83.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	83.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	83.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	112.19
9	0.0	83.00	0.0	0.0	0.0	0.0	151.12	151.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.10	108.66	109.60	111.40
10	0.0	83.00	0.0	0.0	0.0	0.0	151.12	151.12	0.0	0.0	0.0	0.0	0.0	0.0	106.57	107.06	107.68	108.27	109.11	110.64
11	0.0	83.00	0.0	0.0	0.0	0.0	151.12	0.0	0.0	0.0	0.0	104.56	105.05	105.53	106.14	106.73	107.34	107.92	108.53	109.40
12	0.0	83.10	0.0	0.0	0.0	0.0	151.12	0.0	0.0	0.0	0.0	104.05	104.59	105.17	105.80	106.43	107.04	107.60	108.10	108.69
13	0.0	83.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	102.67	103.39	103.90	104.58	105.35	106.10	106.77	107.32	107.78	108.27
14	0.0	83.30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	101.31	101.93	102.57	103.13	103.85	104.78	105.78	106.57	107.16	107.60	108.04
15	0.0	83.40	0.0	0.0	0.0	0.0	0.0	0.0	100.53	100.54	101.14	101.74	102.31	103.00	103.95	104.88	0.0	0.0	0.0	0.0
16	0.0	83.50	0.0	0.0	0.0	0.0	0.0	101.03	0.0	99.57	100.10	100.75	101.41	102.03	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	83.60	87.32	0.0	0.0	0.0	0.0	0.0	0.0	98.52	99.07	99.73	100.62	101.29	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	83.70	87.43	89.98	0.0	0.0	0.0	~~96.84~~	97.11	97.48	97.85	98.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	83.80	87.47	90.02	91.63	91.84	91.95	~~95.11~~	96.59	96.81	96.90	96.82	96.46	0.0	0.0	0.0	0.0	0.0	0.0	0.0

20	0.0	83.90	87.51	90.09	91.76	91.93	91.96	94.87	95.65	95.95	96.13	96.16	96.05	95.81	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	84.00	87.53	90.14	91.96	91.96	91.97	93.91	94.65	95.17	95.48	95.62	95.63	95.55	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	84.20	87.56	90.22	91.95	91.99	91.99	93.78	94.57	94.82	95.06	95.23	95.32	95.39	95.47	0.0	0.0	0.0	0.0	0.0
23	0.0	84.40	87.61	90.35	92.09	92.01	92.01	93.65	94.27	94.50	94.75	94.95	95.13	95.32	95.57	95.91	96.41	0.0	0.0	0.0
24	0.0	84.60	87.68	90.48	92.01	92.03	92.02	93.50	93.61	94.12	94.47	94.72	94.97	95.26	95.65	96.19	96.97	98.15	0.0	0.0
25	0.0	84.80	87.80	90.57	92.08	92.05	92.03	93.38	93.25	93.73	94.16	94.49	94.79	95.14	95.65	96.40	97.43	99.41	103.33	107.94
26	0.0	85.00	87.98	90.66	92.12	92.07	92.04	93.16	92.01	93.09	93.67	94.12	94.51	94.92	95.48	96.32	97.54	99.55	103.83	108.77
27	0.0	85.20	88.20	90.78	92.31	92.10	92.03	93.03	92.06	92.59	93.14	93.58	94.01	94.45	95.04	95.87	97.11	99.53	104.28	109.53
28	0.0	85.40	88.39	90.88	92.34	92.11	91.99	92.95	91.64	92.02	92.50	92.94	93.34	93.76	94.27	94.98	96.04	0.0	0.0	0.0
29	0.0	85.60	88.52	90.95	92.46	92.11	91.92	92.87	91.11	91.63	92.05	92.43	92.78	93.16	93.57	94.09	0.0	0.0	0.0	0.0
30	0.0	85.80	88.62	91.00	92.58	92.08	91.81	92.80	91.18	91.50	91.84	92.18	92.49	92.75	93.00	93.21	0.0	0.0	0.0	0.0
31	0.0	86.00	88.71	91.05	92.86	92.04	91.64	92.73	90.94	91.32	91.66	91.96	92.23	92.45	92.57	92.55	0.0	0.0	0.0	0.0
32	0.0	86.20	88.81	91.10	92.88	91.99	91.39	90.67	90.96	91.25	91.54	91.80	92.05	92.24	92.37	92.43	92.43	0.0	0.0	0.0
33	0.0	86.40	88.90	91.13	92.84	91.96	91.32	90.74	90.99	91.26	91.51	91.74	91.96	92.15	92.30	92.39	92.43	0.0	0.0	0.0
34	0.0	86.60	88.99	91.16	92.78	91.93	91.31	90.79	91.05	91.31	91.55	91.76	91.95	92.14	92.30	92.41	92.48	92.50	0.0	0.0
35	0.0	86.80	89.09	91.18	92.72	91.92	91.33	90.85	91.12	91.38	91.62	91.83	92.02	92.20	92.36	92.49	92.57	92.64	0.0	0.0
36	0.0	87.00	89.18	91.20	92.65	91.91	91.36	90.92	91.20	91.47	91.72	91.94	92.13	92.31	92.48	92.62	92.71	92.85	0.0	0.0
37	0.0	87.10	89.27	91.21	92.60	91.92	91.40	91.00	91.29	91.57	91.84	92.07	92.27	92.46	92.64	92.79	92.92	93.05	0.0	0.0
38	0.0	87.20	89.35	91.22	92.55	91.94	91.46	91.08	91.40	91.70	91.98	92.22	92.43	92.63	92.81	92.98	93.12	93.23	93.39	0.0
39	0.0	87.30	89.42	91.22	92.51	91.97	91.54	91.16	91.52	91.85	92.13	92.39	92.61	92.80	92.99	93.15	93.30	93.42	93.55	0.0

40	0.0	87.40	89.49	91.21	92.45	92.02	91.65	91.22	91.68	92.03	92.33	92.58	92.79	92.98	93.16	93.33	93.47	93.59	93.71	93.97
41	0.0	87.50	89.55	91.21	92.36	92.08	91.83	91.51	91.94	92.27	92.55	92.79	92.99	93.18	93.35	93.50	93.64	93.77	93.89	94.12
42	0.0	87.60	89.62	91.20	92.19	92.16	92.09	92.08	92.29	92.54	92.79	93.01	93.20	93.38	93.54	93.70	93.84	93.97	94.09	94.31
43	0.0	87.70	89.69	91.21	92.10	92.25	92.32	92.43	92.60	92.81	93.03	93.23	93.42	93.59	93.75	93.90	94.04	94.18	94.31	94.50
44	0.0	87.80	89.77	91.22	92.08	92.35	92.53	92.69	92.87	93.06	93.26	93.46	93.64	93.81	93.97	94.12	94.26	94.39	94.54	94.75
45	0.0	87.90	89.85	91.25	92.09	92.46	92.71	92.92	93.10	93.30	93.50	93.69	93.87	94.03	94.19	94.34	94.48	94.63	94.80	95.04
46	0.0	88.00	89.93	91.30	92.13	92.57	92.89	93.13	93.34	93.54	93.74	93.93	94.10	94.26	94.42	94.57	94.72	94.88	95.06	95.32
47	0.0	88.20	90.05	91.37	92.20	92.73	93.12	93.40	93.63	93.84	94.05	94.23	94.40	94.56	94.72	94.87	95.04	95.21	95.39	95.66
48	0.0	88.50	90.25	91.52	92.36	93.01	93.49	93.82	94.06	94.28	94.47	94.65	94.81	94.97	95.13	95.30	95.47	95.64	95.83	96.11
49	0.0	89.00	90.60	91.83	92.78	93.61	94.15	94.46	94.69	94.89	95.06	95.23	95.39	95.56	95.72	95.89	96.05	96.24	96.43	96.69
50	0.0	90.00	91.32	92.66	93.75	94.53	95.02	95.35	95.58	95.76	95.93	96.10	96.26	96.42	96.58	96.74	96.91	97.10	97.30	97.59
51	0.0	91.00	92.59	94.14	95.16	95.77	96.17	96.45	96.68	96.92	97.17	97.37	97.53	97.69	97.86	98.03	98.21	98.42	98.65	98.97
52	0.0	92.00	94.00	96.00	97.00	97.50	97.70	98.00	98.20	98.50	98.80	99.00	99.30	99.50	99.70	100.00	99.60	99.85	100.12	100.52
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0														
2	0.0	0.0	0.0	140.01	139.00	0.0														
3	0.0	0.0	0.0	142.43	144.00	0.0														
4	0.0	0.0	0.0	142.89	146.00	0.0														
5	0.0	0.0	135.80	141.64	147.00	0.0														
6	0.0	0.0	134.57	140.72	148.00	0.0														
7	0.0	0.0	133.77	140.33	149.00	0.0														
8	115.06	121.28	132.87	140.14	148.60	0.0														
9	114.71	120.82	132.22	140.13	148.60	0.0														

DRAWDOWN

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	-0.00	0.0	0.0														
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	-0.00	0.0	0.0														
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	-0.00	0.0	0.0														
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	-0.01	-0.00	0.0	0.0														
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	-0.01	-0.00	0.0	0.0														
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	-0.01	-0.00	0.0	0.0														
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04
	0.02	-0.01	-0.01	-0.00	0.0	0.0														
9	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.02	0.03	0.04
	0.03	-0.01	-0.01	-0.00	0.0	0.0														
10	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.01	0.01	0.02	0.03	0.03
	0.03	-0.00	-0.01	-0.00	0.0	0.0														
11	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	-0.01	-0.01	-0.00	0.00	0.01	0.01	0.02	0.02	0.03
	0.0	0.00	0.0	-0.00	0.0	0.0														
12	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	-0.02	-0.03	-0.02	-0.02	-0.02	-0.04	-0.02	-0.01	-0.01
	0.0	0.0	0.0	0.0	0.0	0.0														
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.02	-0.02	-0.01	-0.01	-0.00	0.00	0.00	0.01	0.01	0.02
	0.0	0.0	0.0	0.0	0.0	0.0														
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.00	0.00	0.01	0.01	0.01
	0.0	0.0	0.0	0.0	0.0	0.0														
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.03	-0.04	-0.03	-0.02	-0.02	-0.02	-0.01	-0.01	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.07	-0.05	-0.04	-0.03	-0.02	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														
17	0.0	0.0	-0.35	0.0	0.0	0.0	0.0	0.0	0.0	-0.11	-0.07	-0.05	-0.04	-0.03	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														
18	0.0	0.0	-0.36	-0.60	0.0	0.0	0.0	[illegible]	-0.30	-0.17	-0.11	-0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														
19	0.0	0.0	-0.37	-0.60	-0.70	0.26	1.32	[illegible]	-0.34	-0.18	-0.10	-0.05	-0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														

20	0.0 0.0	0.0 0.0	-0.37 0.0	-0.61 0.0	-0.72 0.0	0.24 0.0	1.17	0.00	-0.48	-0.17	-0.06	-0.02	0.02	0.07	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0 0.0	0.0 0.0	-0.37 0.0	-0.62 0.0	-0.87 0.0	0.25 0.0	1.17	0.01	-0.11	-0.08	-0.01	0.04	0.08	0.12	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0 0.0	0.0 0.0	-0.38 0.0	-0.62 0.0	-0.80 0.0	0.24 0.0	1.12	0.01	-0.28	-0.07	0.05	0.10	0.14	0.15	0.14	0.0	0.0	0.0	0.0	0.0
23	0.0 0.0	0.0 0.0	-0.38 0.0	-0.63 0.0	-0.88 0.0	0.18 0.0	1.00	0.01	-0.13	0.06	0.15	0.19	0.20	0.17	0.10	-0.03	-0.22	0.0	0.0	0.0
24	0.0 0.0	0.0 0.0	-0.38 0.0	-0.64 0.0	-0.76 0.0	0.11 0.0	0.87	0.01	0.38	0.32	0.31	0.31	0.28	0.21	0.07	-0.15	-0.51	-0.73	0.0	0.0
25	0.0 -1.55	0.0 0.0	-0.39 0.0	-0.66 0.0	-0.80 0.0	0.03 0.0	0.72	0.00	0.62	0.59	0.51	0.46	0.40	0.29	0.10	-0.22	-0.66	-1.12	-1.14	-1.15
26	0.0 -1.61	0.0 0.0	-0.40 0.0	-0.68 0.0	-0.81 0.0	0.01 0.0	0.64	0.01	1.65	1.04	0.82	0.69	0.57	0.43	0.21	-0.16	-0.71	-1.29	-0.98	-0.83
27	0.0 -2.05	0.0 -1.81	-0.42 0.0	-0.72 0.0	-0.95 0.0	-0.00 0.0	0.60	0.01	1.38	1.29	1.14	1.01	0.87	0.71	0.47	0.07	-0.58	-1.32	-0.84	-0.80
28	0.0 -2.56	0.0 -1.75	-0.44 -1.07	-0.76 0.0	-0.94 0.0	-0.01 0.0	0.59	0.01	1.66	1.63	1.51	1.39	1.27	1.12	0.90	0.55	-0.03	0.0	0.0	0.0
29	0.0 -2.66	0.0 -1.61	-0.42 -1.02	-0.77 -0.09	-1.03 0.0	-0.01 0.0	0.63	0.01	2.07	1.87	1.75	1.65	1.54	1.41	1.24	0.96	95.54	0.0	0.0	0.0
30	0.0 -1.76	0.0 -1.44	-0.38 -0.95	-0.76 -0.08	-1.09 0.0	0.04 0.0	0.72	0.01	1.91	1.88	1.80	1.71	1.62	1.54	1.45	1.36	0.0	0.0	0.0	0.0
31	0.0 -0.93	0.0 -1.27	-0.35 -0.88	-0.76 -0.08	-1.30 0.0	0.11 0.0	0.87	0.04	2.06	1.93	1.84	1.77	1.70	1.64	1.61	1.68	94.15	0.0	0.0	0.0
32	0.0 -0.91	0.0 -1.09	-0.32 -0.85	-0.74 -0.08	-1.26 0.0	0.18 0.0	1.12	2.09	2.01	1.93	1.86	1.80	1.74	1.69	1.66	1.66	1.64	94.08	0.0	0.0
33	0.0 -0.92	0.0 -0.98	-0.31 -0.81	-0.70 0.0	-1.18 0.0	0.23 0.0	1.21	2.03	1.97	1.91	1.85	1.80	1.75	1.70	1.66	1.64	1.62	94.07	0.0	0.0
34	0.0 -0.92	0.0 -0.92	-0.29 -0.77	-0.66 0.0	-1.10 0.0	0.27 0.0	1.24	2.01	1.95	1.88	1.82	1.77	1.73	1.68	1.64	1.60	1.59	1.59	94.09	0.0
35	0.0 0.0	0.0 -0.89	-0.28 -0.74	-0.61 -0.22	-1.03 0.0	0.32 0.0	1.26	1.99	1.92	1.85	1.79	1.74	1.69	1.64	1.59	1.55	1.53	1.50	0.0	0.0
36	0.0 0.0	0.0 0.0	-0.26 -0.69	-0.57 -0.23	-0.95 0.0	0.36 0.0	1.28	1.97	1.89	1.82	1.75	1.69	1.64	1.58	1.53	1.49	1.46	1.39	0.0	0.0
37	0.0 0.0	0.0 0.0	-0.24 -0.64	-0.53 -0.24	-0.87 0.0	0.39 0.0	1.28	1.95	1.86	1.78	1.70	1.64	1.58	1.52	1.47	1.42	1.38	1.32	94.48	0.0
38	0.0 0.0	0.0 0.0	-0.22 -0.59	-0.48 -0.23	-0.79 0.0	0.42 0.0	1.28	1.94	1.83	1.73	1.65	1.58	1.51	1.46	1.40	1.35	1.30	1.27	1.20	0.0
39	0.0 0.0	0.0 0.0	-0.20 -0.56	-0.43 -0.23	-0.70 0.0	0.44 0.0	1.28	1.94	1.79	1.67	1.58	1.51	1.45	1.39	1.34	1.29	1.24	1.21	1.16	0.0

40	0.0	0.0	-0.18	-0.37	-0.59	0.46	1.25	1.96	1.73	1.59	1.50	1.43	1.37	1.32	1.27	1.23	1.19	1.16	1.13	1.05
	0.0	0.0	0.0	-0.23	-0.01	0.0														
41	0.0	0.0	-0.16	-0.30	-0.43	0.48	1.15	1.78	1.57	1.46	1.39	1.34	1.29	1.25	1.21	1.17	1.14	1.11	1.09	1.01
	0.0	0.0	0.0	-0.22	-0.01	0.0														
42	0.0	0.0	-0.13	-0.23	-0.19	0.49	0.99	1.30	1.33	1.30	1.27	1.24	1.21	1.18	1.15	1.12	1.09	1.06	1.03	0.98
	0.0	0.0	0.0	0.0	-0.01	0.0														
43	0.0	0.0	-0.11	-0.16	-0.03	0.49	0.86	1.07	1.14	1.16	1.16	1.15	1.13	1.10	1.08	1.06	1.03	1.01	0.99	0.95
	0.0	0.0	0.0	0.0	-0.00	0.0														
44	0.0	0.0	-0.09	-0.10	0.08	0.48	0.77	0.93	1.00	1.04	1.05	1.06	1.05	1.03	1.02	1.00	0.98	0.96	0.94	0.91
	0.78	0.0	0.0	0.0	-0.00	0.0														
45	0.0	0.0	-0.07	-0.05	0.14	0.47	0.70	0.83	0.90	0.94	0.96	0.97	0.97	0.96	0.95	0.94	0.92	0.91	0.88	0.85
	0.75	0.0	0.0	0.0	-0.00	0.0														
46	0.0	0.0	-0.05	-0.01	0.18	0.46	0.65	0.76	0.82	0.86	0.89	0.90	0.90	0.90	0.89	0.88	0.87	0.85	0.83	0.80
	0.73	0.51	0.09	0.0	0.0	0.0														
47	0.0	0.0	-0.04	0.02	0.21	0.44	0.60	0.69	0.74	0.78	0.80	0.82	0.82	0.82	0.82	0.81	0.80	0.79	0.77	0.74
	0.69	0.52	0.08	-0.05	0.0	0.0														
48	0.0	0.0	-0.01	0.06	0.23	0.42	0.54	0.61	0.66	0.69	0.71	0.72	0.73	0.73	0.73	0.72	0.71	0.70	0.69	0.66
	0.62	0.54	0.10	-0.06	0.0	0.0														
49	0.0	0.0	0.01	0.08	0.22	0.37	0.47	0.53	0.56	0.58	0.60	0.61	0.61	0.62	0.61	0.61	0.61	0.60	0.59	0.57
	0.55	0.50	0.22	0.0	0.0	0.0														
50	0.0	0.0	0.02	0.09	0.19	0.26	0.33	0.38	0.41	0.44	0.45	0.46	0.47	0.47	0.48	0.48	0.47	0.47	0.46	0.45
	0.42	0.36	0.19	0.11	0.0	0.0														
51	0.0	0.0	0.02	0.06	0.10	0.13	0.16	0.18	0.20	0.22	0.24	0.26	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28
	0.27	0.24	0.17	0.09	0.0	0.0														
52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.04	0.05
	0.07	0.09	0.08	0.04	0.0	0.0														
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														

HEAD AND DRAWDOWN IN PUMPING WELLS

I	J	WELL RADIUS	HEAD	DRAWDOWN
21	5	0.50	92.80	-1.72
23	5	0.50	92.93	-1.72
25	5	0.50	92.40	-1.12
27	5	0.50	92.95	-1.59
29	5	0.50	92.74	-1.30
31	5	0.50	93.90	-2.34
32	5	0.50	93.50	-1.88
33	5	0.50	93.30	-1.65
34	5	0.50	93.23	-1.55
35	5	0.50	93.17	-1.47
36	5	0.50	93.10	-1.40

37	5	0.50	93.02	-1.30
38	5	0.50	92.98	-1.22
39	5	0.50	92.91	-1.11
40	5	0.50	92.88	-1.02
41	5	0.50	92.80	-0.88
21	9	0.50	94.04	0.50
24	9	0.50	93.01	0.98
26	9	0.50	90.40	3.26
29	9	0.50	90.63	2.55
31	9	0.50	90.64	2.36
32	8	0.50	90.11	2.65
33	8	0.50	90.30	2.47
34	8	0.50	90.38	2.42
35	8	0.50	90.46	2.38
36	8	0.50	90.55	2.34
37	8	0.50	90.62	2.33
38	8	0.50	90.72	2.30
39	8	0.50	90.76	2.34
40	8	0.50	90.62	2.56
41	8	0.50	90.91	2.38

SIMULATION 10

PUMPING PERIOD NO. 1Ø 180.00 DAYS

NUMBER OF TIME STEPS= 12

DELT IN HOURS = 11.185

MULTIPLIER FOR DELT = 1.500

31 WELLS

	I	J	PUMPING RATE	WELL RADIUS
RW16	21	5	0.05	0.50
RW15	23	5	0.05	0.50
RW14	25	5	0.05	0.50
RW13	27	5	0.05	0.50
RW12	29	5	0.05	0.50
RW11	31	5	0.06	0.50
RW10	32	5	0.22	0.50
RW9	33	5	0.22	0.50
RW8	34	5	0.22	0.50
RW7	35	5	0.22	0.50
RW6	36	5	0.22	0.50
RW5	37	5	0.22	0.50
RW4	38	5	0.22	0.50
RW3	39	5	0.22	0.50
RW2	40	5	0.22	0.50
RW1	41	5	0.22	0.50
DW15	21	9	-0.06	0.50
DW14	24	9	-0.06	0.50
DW13	26	9	-0.06	0.50
DW12	29	9	-0.06	0.50
DW11	31	9	-0.06	0.50
DW10	32	8	-0.22	0.50
DW9	33	8	-0.22	0.50
DW8	34	8	-0.22	0.50
DW7	35	8	-0.22	0.50
DW6	36	8	-0.22	0.50
DW5	37	8	-0.22	0.50
DW4	38	8	-0.22	0.50
DW3	39	8	-0.22	0.50
DW2	40	8	-0.22	0.50
DW1	41	8	-0.22	0.50

```
---------------------------------------------------------
I               TIME STEP NUMBER =        9              I
---------------------------------------------------------

SIZE OF TIME STEP IN SECONDS=    1547928.00

     TOTAL SIMULATION TIME IN SECONDS=    4522989.00
                              MINUTES=      75383.12
                                HOURS=       1256.39
                                 DAYS=         52.35
                                YEARS=          0.14

DURATION OF CURRENT PUMPING PERIOD IN DAYS=    52.35
                                    YEARS=      0.14

CUMULATIVE MASS BALANCE*          L**3                RATES FOR THIS TIME STEP*              L**3/T
------------------------                              ------------------------

      SOURCES*                                                        STORAGE =        -0.0011
      --------                                                       RECHARGE =         0.0
           STORAGE =         -38882.96                          CONSTANT FLUX =         2.4810
          RECHARGE =              0.0                                 PUMPING =        -2.4800
     CONSTANT FLUX =       11221514.0                      EVAPOTRANSPIRATION =         0.0
     CONSTANT HEAD =       18816704.0                          CONSTANT HEAD*
           LEAKAGE =              0.0                                      IN =         4.1769
     TOTAL SOURCES =       29999328.0                                     OUT =        -4.1399
                                                                     LEAKAGE*
      DISCHARGES*                               FROM PREVIOUS PUMPING PERIOD =         0.0
      -----------                                                       TOTAL =         0.0
 EVAPOTRANSPIRATION =             0.0
     CONSTANT HEAD =       18801232.0                           SUM OF RATES =         0.0369
   QUANTITY PUMPED =       11216990.0
           LEAKAGE =              0.0
   TOTAL DISCHARGE =       30018208.0

 DISCHARGE-SOURCES =         18880.00
PER CENT DIFFERENCE =             0.06

MAXIMUM HEAD CHANGE FOR EACH ITERATION*
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     0.0157

MAXIMUM CHANGE IN HEAD FOR THIS TIME STEP =     0.016
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TIME STEP *  1  2  3  4  5  6  7  8  9
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ITERATIONS* 15  8  8 10 11 10 10 10  0
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```

HEAD MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	83.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	83.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	83.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	83.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	112.23
9	0.0	83.00	0.0	0.0	0.0	0.0	151.12	151.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.19	108.74	109.67	111.45
10	0.0	83.00	0.0	0.0	0.0	0.0	151.12	151.12	0.0	0.0	0.0	0.0	0.0	0.0	106.68	107.16	107.77	108.36	109.18	110.69
11	0.0	83.00	0.0	0.0	0.0	0.0	151.12	0.0	0.0	0.0	0.0	104.71	105.19	105.66	106.25	106.84	107.44	108.01	108.61	109.47
12	0.0	83.10	0.0	0.0	0.0	0.0	151.12	0.0	0.0	0.0	0.0	104.23	104.74	105.31	105.92	106.54	107.14	107.69	108.19	108.76
13	0.0	83.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	102.90	103.60	104.09	104.74	105.49	106.22	106.88	107.42	107.87	108.35
14	0.0	83.30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	101.57	102.19	102.81	103.35	104.04	104.94	105.91	106.68	107.26	107.69	108.12
15	0.0	83.40	0.0	0.0	0.0	0.0	0.0	0.0	100.85	100.89	101.45	102.03	102.57	103.23	104.14	105.03	0.0	0.0	0.0	0.0
16	0.0	83.50	0.0	0.0	0.0	0.0	0.0	101.03	0.0	100.08	100.53	101.11	101.73	102.30	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	83.60	86.98	0.0	0.0	0.0	0.0	0.0	0.0	99.15	99.60	100.19	101.01	101.61	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	83.70	87.07	89.29	0.0	0.0	0.0	96.56	97.91	98.23	98.54	98.77	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	83.80	87.12	89.32	90.59	90.87	90.98	95.11	97.42	97.60	97.67	97.58	97.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0

20	0.0	83.90	87.15	89.38	90.68	90.93	90.99	94.07	96.52	96.78	96.93	96.94	96.83	96.61	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	84.00	87.18	89.44	90.82	90.97	91.02	93.90	95.58	96.03	96.30	96.43	96.43	96.36	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	84.20	87.22	89.54	90.88	91.03	91.06	93.77	95.47	95.68	95.89	96.04	96.12	96.18	96.25	0.0	0.0	0.0	0.0	0.0
23	0.0	84.40	87.27	89.69	91.03	91.09	91.11	93.65	95.16	95.36	95.57	95.75	95.92	96.10	96.34	96.70	97.17	0.0	0.0	0.0
24	0.0	84.60	87.36	89.84	91.07	91.15	91.16	93.49	94.56	94.98	95.27	95.49	95.72	96.01	96.40	96.93	97.66	98.75	0.0	0.0
25	0.0	84.80	87.52	89.96	91.20	91.22	91.23	93.38	94.15	94.56	94.93	95.23	95.50	95.84	96.35	97.10	98.10	99.92	103.59	108.08
26	0.0	85.00	87.75	90.11	91.34	91.33	91.35	93.16	92.95	93.88	94.39	94.79	95.16	95.57	96.12	96.96	98.20	100.13	104.10	108.88
27	0.0	85.20	88.03	90.31	91.65	91.49	91.46	93.02	92.77	93.25	93.76	94.17	94.58	95.01	95.59	96.45	97.76	100.10	104.50	109.62
28	0.0	85.40	88.27	90.51	91.79	91.64	91.55	92.95	92.20	92.54	92.99	93.42	93.80	94.21	94.71	95.43	96.58	0.0	0.0	0.0
29	0.0	85.60	88.43	90.65	91.97	91.73	91.60	92.87	91.61	92.06	92.45	92.82	93.17	93.53	93.94	94.42	0.0	0.0	0.0	0.0
30	0.0	85.80	88.53	90.74	92.09	91.79	91.58	92.80	91.54	91.85	92.19	92.52	92.83	93.10	93.35	93.56	0.0	0.0	0.0	0.0
31	0.0	86.00	88.64	90.83	92.33	91.82	91.50	92.72	91.21	91.59	91.94	92.26	92.54	92.76	92.90	92.89	0.0	0.0	0.0	0.0
32	0.0	86.20	88.75	90.91	92.56	91.84	91.33	90.73	91.11	91.45	91.76	92.05	92.31	92.51	92.65	92.70	92.68	0.0	0.0	0.0
33	0.0	86.40	88.85	90.99	92.62	91.86	91.31	90.80	91.12	91.43	91.71	91.95	92.18	92.39	92.54	92.63	92.66	0.0	0.0	0.0
34	0.0	86.60	88.95	91.06	92.65	91.88	91.34	90.87	91.17	91.46	91.73	91.95	92.16	92.35	92.52	92.63	92.69	92.70	0.0	0.0
35	0.0	86.80	89.06	91.12	92.64	91.91	91.38	90.95	91.25	91.54	91.79	92.02	92.22	92.40	92.56	92.69	92.76	92.82	0.0	0.0
36	0.0	87.00	89.16	91.16	92.62	91.94	91.45	91.05	91.35	91.63	91.90	92.13	92.32	92.50	92.67	92.81	92.90	93.03	0.0	0.0
37	0.0	87.10	89.25	91.19	92.60	91.99	91.53	91.16	91.47	91.76	92.03	92.26	92.46	92.65	92.82	92.97	93.09	93.21	0.0	0.0
38	0.0	87.20	89.33	91.21	92.58	92.04	91.62	91.28	91.61	91.91	92.18	92.41	92.62	92.81	92.99	93.15	93.29	93.39	93.54	0.0
39	0.0	87.30	89.41	91.23	92.56	92.10	91.75	91.42	91.77	92.08	92.35	92.59	92.80	92.99	93.16	93.32	93.46	93.57	93.70	0.0

40	0.0	87.40	89.49	91.23	92.52	92.17	91.90	91.62	91.98	92.28	92.55	92.78	92.98	93.16	93.33	93.49	93.63	93.74	93.86	94.11
41	0.0	87.50	89.56	91.24	92.44	92.25	92.10	91.91	92.24	92.52	92.77	92.99	93.18	93.35	93.51	93.66	93.80	93.92	94.03	94.25
42	0.0	87.60	89.63	91.24	92.28	92.32	92.32	92.37	92.55	92.78	93.00	93.20	93.38	93.55	93.70	93.85	93.99	94.11	94.23	94.44
43	0.0	87.70	89.70	91.25	92.20	92.41	92.53	92.66	92.83	93.02	93.22	93.41	93.59	93.75	93.90	94.05	94.19	94.31	94.44	94.63
44	0.0	87.80	89.78	91.27	92.18	92.50	92.71	92.89	93.06	93.25	93.44	93.63	93.80	93.96	94.11	94.26	94.39	94.53	94.67	94.87
45	0.0	87.90	89.86	91.30	92.19	92.60	92.87	93.09	93.28	93.47	93.67	93.85	94.02	94.18	94.33	94.47	94.61	94.76	94.92	95.15
46	0.0	88.00	89.95	91.35	92.22	92.70	93.04	93.29	93.49	93.70	93.90	94.08	94.24	94.40	94.55	94.70	94.84	95.00	95.17	95.42
47	0.0	88.20	90.07	91.42	92.29	92.85	93.25	93.54	93.77	93.98	94.18	94.36	94.53	94.69	94.84	94.99	95.15	95.32	95.49	95.76
48	0.0	88.50	90.26	91.57	92.44	93.11	93.61	93.94	94.18	94.40	94.59	94.76	94.93	95.09	95.24	95.41	95.57	95.74	95.93	96.20
49	0.0	89.00	90.62	91.86	92.84	93.69	94.25	94.56	94.79	94.99	95.16	95.33	95.49	95.65	95.82	95.98	96.14	96.32	96.52	96.77
50	0.0	90.00	91.34	92.69	93.80	94.58	95.08	95.42	95.65	95.83	96.00	96.18	96.34	96.49	96.65	96.81	96.98	97.16	97.37	97.65
51	0.0	91.00	92.59	94.16	95.18	95.79	96.20	96.48	96.71	96.96	97.21	97.41	97.57	97.73	97.90	98.07	98.25	98.46	98.69	99.01
52	0.0	92.00	94.00	96.00	97.00	97.50	97.70	98.00	98.20	98.50	98.80	99.00	99.30	99.50	99.70	100.00	99.60	99.85	100.13	100.53
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	140.01	139.00	0.0
3	0.0	0.0	0.0	142.43	144.00	0.0
4	0.0	0.0	0.0	142.89	146.00	0.0
5	0.0	0.0	135.80	141.64	147.00	0.0
6	0.0	0.0	134.57	140.72	148.00	0.0
7	0.0	0.0	133.77	140.33	149.00	0.0
8	115.07	121.28	132.87	140.14	148.60	0.0
9	114.73	120.83	132.22	140.13	148.60	0.0

DRAWDOWN

1	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0 0.0	0.0 0.0	0.0 0.0	0.0 -0.00	0.0 0.0	0.0 0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0 0.0	0.0 0.0	0.0 0.0	0.0 -0.00	0.0 0.0	0.0 0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0 0.0	0.0 0.0	0.0 0.0	0.0 -0.00	0.0 0.0	0.0 0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0 0.0	0.0 0.0	0.0 -0.01	0.0 -0.00	0.0 0.0	0.0 0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0 0.0	0.0 0.0	0.0 -0.01	0.0 -0.00	0.0 0.0	0.0 0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0 0.0	0.0 0.0	0.0 -0.01	0.0 -0.00	0.0 0.0	0.0 0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0 0.00	0.0 -0.01	0.0 -0.01	0.0 -0.00	0.0 0.0	0.0 0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
9	0.0 0.00	0.0 -0.01	0.0 -0.01	0.0 -0.00	0.0 0.0	0.0 0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.07	-0.05	-0.03	-0.01
10	0.0 0.00	0.0 -0.01	0.0 -0.01	0.0 -0.00	0.0 0.0	0.0 0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	-0.10	-0.09	-0.08	-0.06	-0.05	-0.02
11	0.0 0.0	0.0 -0.00	0.0 0.0	0.0 -0.00	0.0 0.0	0.0 0.0	0.00	0.0	0.0	0.0	0.0	-0.16	-0.15	-0.13	-0.12	-0.10	-0.09	-0.07	-0.06	-0.04
12	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00	0.0	0.0	0.0	0.0	-0.20	-0.18	-0.16	-0.14	-0.13	-0.11	-0.11	-0.10	-0.08
13	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0	0.0	0.0	0.0	-0.24	-0.22	-0.20	-0.17	-0.14	-0.12	-0.10	-0.09	-0.08	-0.06
14	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0	0.0	0.0	-0.28	-0.29	-0.26	-0.23	-0.20	-0.16	-0.13	-0.11	-0.09	-0.08	-0.07
15	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0	0.0	-0.35	-0.38	-0.34	-0.31	-0.28	-0.24	-0.19	-0.16	0.0	0.0	0.0	0.0
16	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0	0.0	0.0	-0.57	-0.47	-0.40	-0.35	-0.29	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0 0.0	0.0 0.0	-0.01 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0	0.0	0.0	-0.74	-0.60	-0.50	-0.42	-0.35	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0 0.0	0.0 0.0	-0.01 0.0	0.09 0.0	0.0 0.0	0.0 0.0	0.0	-0.00	-1.10	-0.92	-0.79	-0.69	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0 0.0	0.0 0.0	-0.01 0.0	0.09 0.0	0.35 0.0	1.27 0.0	2.30	0.00	-1.17	-0.98	-0.87	-0.81	-0.78	0.0	0.0	0.0	0.0	0.0	0.0	0.0

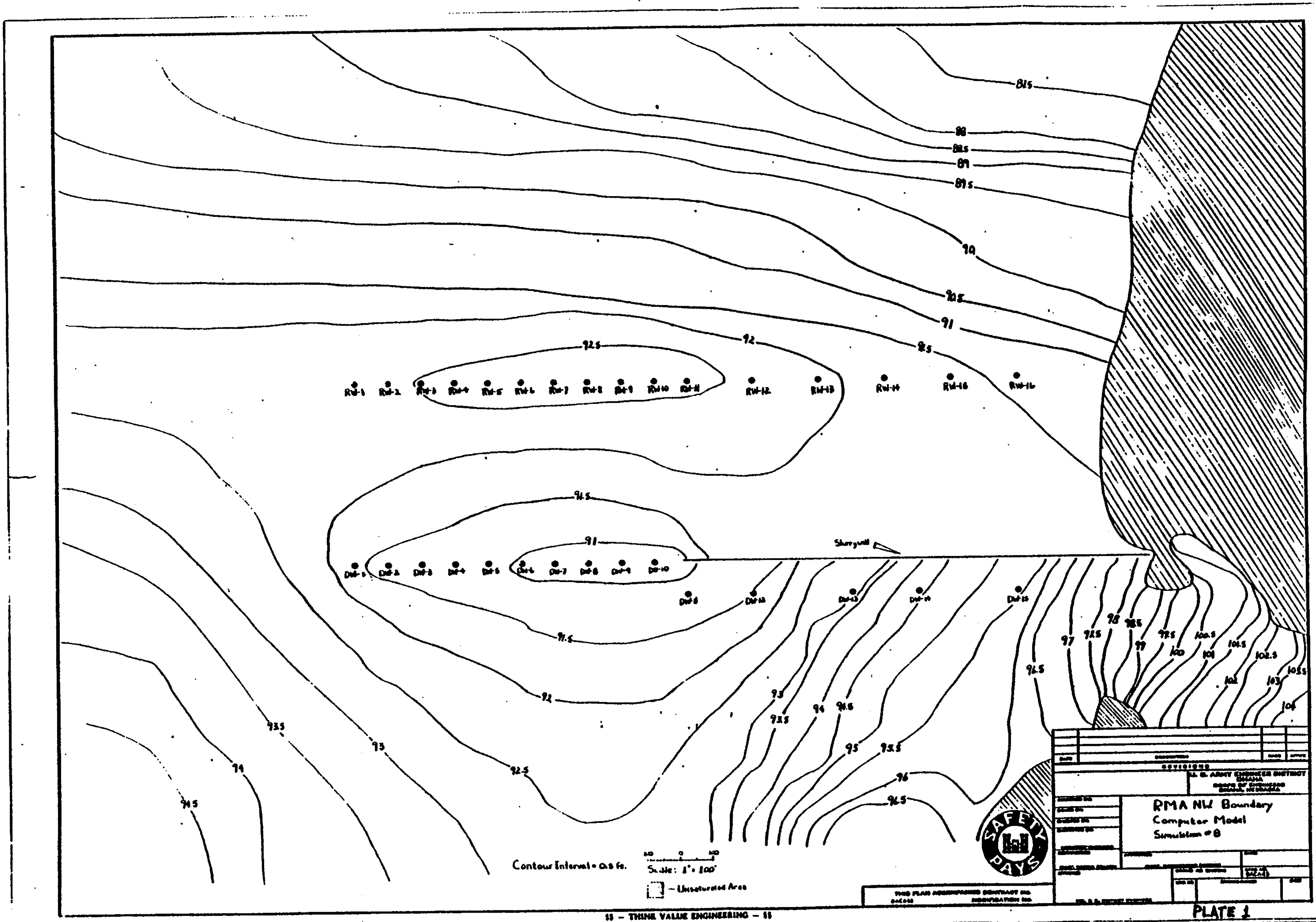
20	0.0 0.0	0.0 0.0	-0.02 0.0	0.09 0.0	0.35 0.0	1.24 0.0	2.13	0.06	-1.35	-0.99	-0.86	-0.80	-0.76	-0.72	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0 0.0	0.0 0.0	-0.02 0.0	0.08 0.0	0.27 0.0	1.24 0.0	2.12	0.01	-1.04	-0.94	-0.84	-0.77	-0.72	-0.69	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0 0.0	0.0 0.0	-0.03 0.0	0.06 0.0	0.27 0.0	1.20 0.0	2.05	0.02	-1.18	-0.93	-0.78	-0.70	-0.66	-0.64	-0.64	0.0	0.0	0.0	0.0	0.0
23	0.0 0.0	0.0 0.0	-0.04 0.0	0.02 0.0	0.19 0.0	1.10 0.0	1.90	0.01	-1.03	-0.80	-0.67	-0.60	-0.58	-0.60	-0.67	-0.83	-0.99	0.0	0.0	0.0
24	0.0 0.0	0.0 0.0	-0.07 0.0	-0.01 0.0	0.17 0.0	0.98 0.0	1.73	0.02	-0.57	-0.54	-0.50	-0.46	-0.47	-0.53	-0.67	-0.89	-1.20	-1.39	0.0	0.0
25	0.0 -1.73	0.0 0.0	-0.11 0.0	-0.04 0.0	0.08 0.0	0.86 0.0	1.52	0.01	-0.28	-0.24	-0.27	-0.28	-0.32	-0.41	-0.60	-0.92	-1.33	-1.63	-1.40	-1.29
26	0.0 -1.79	0.0 0.0	-0.18 0.0	-0.13 0.0	-0.03 0.0	0.75 0.0	1.33	0.01	0.71	0.25	0.10	0.01	-0.08	-0.21	-0.43	-0.80	-1.37	-1.87	-1.24	-0.94
27	0.0 -2.26	0.0 -2.05	-0.25 0.0	-0.26 0.0	-0.30 0.0	0.60 0.0	1.17	0.01	0.67	0.64	0.52	0.42	0.30	0.15	-0.09	-0.51	-1.24	-1.89	-1.05	-0.89
28	0.0 -2.80	0.0 -1.98	-0.32 -1.27	-0.40 0.0	-0.40 0.0	0.46 0.0	1.02	0.01	1.10	1.11	1.02	0.92	0.81	0.67	0.46	0.10	-0.57	0.0	0.0	0.0
29	0.0 -2.91	0.0 -1.83	-0.33 -1.23	-0.47 -0.12	-0.54 0.0	0.36 0.0	0.94	0.01	1.57	1.44	1.35	1.25	1.16	1.03	0.87	0.64	95.54	0.0	0.0	0.0
30	0.0 -2.00	0.0 -1.67	-0.30 -1.15	-0.50 -0.10	-0.60 0.0	0.33 0.0	0.95	0.02	1.54	1.53	1.45	1.37	1.27	1.19	1.10	1.02	0.0	0.0	0.0	0.0
31	0.0 -1.15	0.0 -1.48	-0.28 -1.08	-0.53 -0.11	-0.77 0.0	0.33 0.0	1.01	0.08	1.78	1.66	1.56	1.47	1.39	1.32	1.29	1.33	94.15	0.0	0.0	0.0
32	0.0 -1.11	0.0 -1.30	-0.26 -1.04	-0.55 -0.11	-0.94 0.0	0.33 0.0	1.18	2.03	1.86	1.73	1.63	1.55	1.48	1.42	1.38	1.38	1.39	94.08	0.0	0.0
33	0.0 -1.13	0.0 -1.19	-0.26 -1.01	-0.56 0.0	-0.97 0.0	0.33 0.0	1.22	1.97	1.85	1.75	1.66	1.59	1.52	1.46	1.42	1.40	1.39	94.07	0.0	0.0
34	0.0 -1.13	0.0 -1.13	-0.25 -0.97	-0.56 0.0	-0.97 0.0	0.33 0.0	1.22	1.93	1.82	1.73	1.64	1.58	1.52	1.47	1.42	1.39	1.38	1.38	94.09	0.0
35	0.0 0.0	0.0 -1.09	-0.24 -0.93	-0.55 -0.31	-0.95 0.0	0.33 0.0	1.21	1.89	1.79	1.69	1.61	1.55	1.49	1.44	1.39	1.36	1.34	1.31	0.0	0.0
36	0.0 0.0	0.0 0.0	-0.23 -0.88	-0.53 -0.32	-0.92 0.0	0.33 0.0	1.19	1.84	1.74	1.65	1.57	1.50	1.45	1.39	1.34	1.30	1.28	1.22	0.0	0.0
37	0.0 0.0	0.0 0.0	-0.22 -0.82	-0.51 -0.33	-0.88 0.0	0.32 0.0	1.16	1.79	1.69	1.59	1.51	1.44	1.39	1.33	1.28	1.24	1.20	1.16	94.48	0.0
38	0.0 0.0	0.0 0.0	-0.21 -0.76	-0.48 -0.32	-0.82 0.0	0.32 0.0	1.12	1.74	1.62	1.53	1.45	1.38	1.32	1.27	1.22	1.18	1.14	1.11	1.05	0.0
39	0.0 0.0	0.0 0.0	-0.20 -0.73	-0.44 -0.32	-0.76 0.0	0.31 0.0	1.07	1.67	1.54	1.44	1.37	1.31	1.25	1.21	1.16	1.12	1.08	1.05	1.01	0.0

40	0.0	0.0	-0.18	-0.39	-0.67	0.31	1.00	1.56	1.43	1.34	1.28	1.22	1.18	1.14	1.10	1.07	1.04	1.01	0.98	0.91
	0.0	0.0	0.0	-0.32	-0.01	0.0														
41	0.0	0.0	-0.16	-0.33	-0.52	0.32	0.89	1.37	1.27	1.21	1.17	1.14	1.11	1.08	1.05	1.02	0.99	0.97	0.94	0.88
	0.0	0.0	0.0	-0.31	-0.01	0.0														
42	0.0	0.0	-0.14	-0.26	-0.28	0.33	0.76	1.02	1.07	1.07	1.06	1.05	1.03	1.01	0.99	0.96	0.94	0.92	0.90	0.85
	0.0	0.0	0.0	0.0	-0.01	0.0														
43	0.0	0.0	-0.12	-0.20	-0.13	0.33	0.66	0.84	0.92	0.95	0.96	0.96	0.96	0.94	0.93	0.91	0.89	0.87	0.85	0.82
	0.0	0.0	0.0	0.0	-0.00	0.0														
44	0.0	0.0	-0.10	-0.15	-0.02	0.33	0.59	0.73	0.81	0.85	0.87	0.88	0.89	0.88	0.87	0.86	0.84	0.83	0.81	0.78
	0.68	0.0	0.0	0.0	-0.00	0.0														
45	0.0	0.0	-0.09	-0.10	0.05	0.33	0.54	0.66	0.72	0.77	0.80	0.81	0.82	0.82	0.81	0.81	0.79	0.78	0.76	0.73
	0.65	0.0	0.0	0.0	-0.00	0.0														
46	0.0	0.0	-0.07	-0.06	0.09	0.33	0.50	0.60	0.66	0.71	0.73	0.75	0.76	0.76	0.76	0.75	0.75	0.73	0.72	0.69
	0.63	0.44	0.08	0.0	0.0	0.0														
47	0.0	0.0	-0.05	-0.03	0.12	0.32	0.46	0.55	0.60	0.64	0.66	0.68	0.69	0.70	0.70	0.69	0.69	0.67	0.66	0.64
	0.59	0.45	0.07	-0.04	0.0	0.0														
48	0.0	0.0	-0.03	0.01	0.15	0.31	0.43	0.49	0.53	0.57	0.59	0.60	0.61	0.62	0.62	0.61	0.61	0.60	0.59	0.57
	0.54	0.47	0.08	-0.06	0.0	0.0														
49	0.0	0.0	-0.01	0.04	0.15	0.29	0.38	0.43	0.46	0.48	0.50	0.51	0.52	0.52	0.52	0.52	0.52	0.51	0.50	0.49
	0.47	0.43	0.19	0.0	0.0	0.0														
50	0.0	0.0	0.01	0.06	0.14	0.21	0.27	0.31	0.34	0.36	0.38	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.39
	0.37	0.31	0.17	0.09	0.0	0.0														
51	0.0	0.0	0.01	0.04	0.08	0.11	0.13	0.15	0.17	0.19	0.21	0.22	0.23	0.23	0.24	0.24	0.24	0.24	0.24	0.24
	0.23	0.20	0.14	0.08	0.0	0.0														
52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.03	0.05
	0.06	0.07	0.07	0.04	0.0	0.0														
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0														

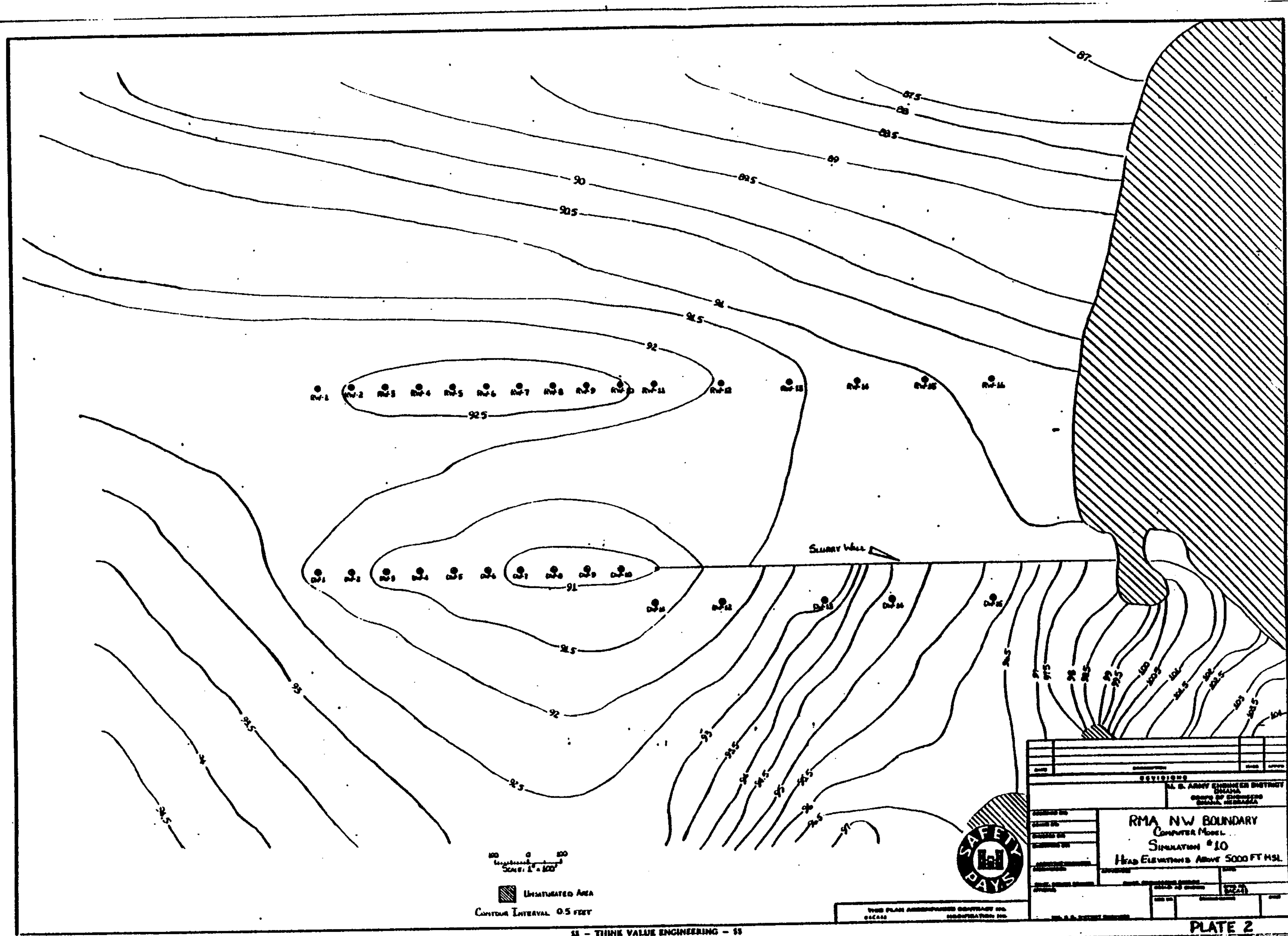
HEAD AND DRAWDOWN IN PUMPING WELLS

I	J	WELL RADIUS	HEAD	DRAWDOWN
21	5	0.50	91.24	-0.16
23	5	0.50	91.46	-0.25
25	5	0.50	91.45	-0.18
27	5	0.50	92.30	-0.94
29	5	0.50	92.25	-0.81
31	5	0.50	92.59	-1.04
32	5	0.50	93.18	-1.56
33	5	0.50	93.09	-1.44
34	5	0.50	93.09	-1.41
35	5	0.50	93.09	-1.39
36	5	0.50	93.07	-1.36

37	5	0.50	93.03	-1.30
38	5	0.50	93.01	-1.25
39	5	0.50	92.97	-1.17
40	5	0.50	92.95	-1.09
41	5	0.50	92.89	-0.96
21	9	0.50	95.08	-0.54
24	9	0.50	94.05	-0.06
26	9	0.50	91.60	2.06
29	9	0.50	91.21	1.98
31	9	0.50	90.96	2.04
32	8	0.50	90.16	2.60
33	8	0.50	90.36	2.41
34	8	0.50	90.45	2.34
35	8	0.50	90.56	2.28
36	8	0.50	90.67	2.22
37	8	0.50	90.78	2.17
38	8	0.50	90.92	2.10
39	8	0.50	91.03	2.07
40	8	0.50	91.23	1.96
41	8	0.50	91.51	1.77



U. S. ARMY ENGINEER DISTRICT
OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA
RMA NW Boundary
Computer Model
Simulation #8
PLATE 1
Contour Interval = 0.5 ft.
Scale: 1" = 100'
– Unsaturated Area
SAFETY PAYS
Slurry wall
$$ – THINK VALUE ENGINEERING – $$



$$ - THINK VALUE ENGINEERING - $$

PLATE 2

APPENDIX B

DRILL LOGS AND INSTALLATION DIAGRAMS

(Bound in separate volume)

APPENDIX C

SANITARY CALCULATIONS

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT Rocky Mnt. Arsenal - NW Bound. PN 37	SHEET NO. 1 OF 8	
ITEM Sizing Disch/Rech. Pressure Lines	BY MCB DATE 12/82	CHKD. BY LLT DATE

Maintain a velocity of 2-5 fps

Develop a formula to determine pipe diameter for Velocity = 3fps

Use Velocity = 3 fps = 180 fpm

$$\frac{Q}{V} = A$$

Q = flow (gpm)
V = velocity (fpm)
A = pipe area (ft²)

$$\frac{Q}{V} = \frac{\pi d^2}{4}$$

d = pipe diameter (ft)

$$\frac{Q}{V}\left(\frac{gal}{min}\ \frac{min}{ft}\ \frac{ft^3}{7.48\ gal}\right) = \frac{\pi d^2}{4}$$

$$\frac{Q\ (4)}{V\ (\pi)(7.48)} = d^2$$

$$\left[\frac{Q\ (4)}{V\ (\pi)(7.48)}\right]^{1/2} = d$$

For $\underline{V = 3\ fps} \Rightarrow 180$ fpm

$$\left[\frac{Q\ (4)}{(180)(\pi)(7.48)}\right]^{1/2}(12) = d$$

... d = pipe diameter (inches)

$$\boxed{\left[(9.457 \times 10^{-4})(Q)\right]^{1/2}(12) \Rightarrow d}$$

for V = 3fps

Checked by Laura Tate

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA NW Boundary		SHEET NO. 2	OF 8
ITEM Sizing Disch./Recharge Pressure Lines		BY MCB	DATE 12/82
		CHKD. BY LLT	DATE

Develop Formula to determine the velocity through the pipe.

V= velocity (fps)
Q= flow (gpm)
A= pipe area.
d= pipe diam. (in.)

$$V = \frac{Q}{A} = \frac{Q(4)}{\pi d^2}$$

$$= \left(\frac{gal}{min}\right)\left(\frac{1}{in^2}\right)\left(\frac{ft^3}{7.48\ gal}\right)\left(\frac{min}{60\ sec}\right)\left(\frac{144\ in^2}{ft^2}\right)$$

$$V = \frac{Q\,(4)(144)}{d^2(\pi)(7.48)(60)}$$

$$\boxed{V = \frac{Q}{d^2}(.4085)}$$

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA PN. 37 NW Boundary	SHEET NO. 3 OF 8	
ITEM Sizing Recharge Water Pipe	BY MCB	DATE
	CHKD. BY LLT	DATE

(RW w/ approximate average flows)

Well	Q (gpm)	Pipe dia. for V=3fps	Use pipe dia.	Vel. (fps)
RW 21 (15 gpm)	15 gpm	1.4	1½"	2.7
RW 20 (15 gpm)	30 gpm	2.0	2"	3.0
RW 19 (15 gpm)	45 gpm	2.5	2½"	3.0
RW 18 (15 gpm)	60 gpm	2.9	3"	2.7
RW 17 (15 gpm)	75 gpm	3.2	3"	3.4
RW 16 (15 gpm)	90 gpm	3.5	4"	2.3
RW 15 (15 gpm)	105 gpm	3.8	4"	2.7
RW 14 (15 gpm)	120 gpm	4.0	4"	3.1
RW 13 (80 gpm)	200 gpm	5.2	6"	2.3
RW 12 (80 gpm)	280 gpm	6.2	6"	3.2
RW 11 (80 gpm)	360 gpm	7.0	6"	4.1
RW 10 (80 gpm)	440 gpm	7.7	8"	2.8
RW 9 (80 gpm)	520 gpm	8.4	8"	3.3

OMAHA DISTRICT — COMPUTATION SHEET — CORPS OF ENGINEERS

PROJECT RMA PN 37 . NW Boundary	SHEET NO. 4	OF 8	
ITEM Sizing Recharge Water Pipe (Cont.)	BY MCB	DATE	
	CHKD. BY LLT	DATE	

(RW w/ approximate average flows)

Well	Q (gpm)	Pipe dia. for V = 3 fps	Use pipe dia	Vel (fps)
RW 8 (80 gpm)	600 gpm	9.0	8"	3.8
RW 7 (80 gpm)	680 gpm	9.6	8"	4.3
RW 6 (80 gpm)	760 gpm	10.2	10"	3.1
RW 5 (80 gpm)	840 gpm	10.7	10"	3.4
RW 4 (80 gpm)	920 gpm	11.2	10"	3.8
RW 3 (80 gpm)	1000 gpm	11.7	10"	4.1
RW 2 (80 gpm)	1080 gpm	12.1	10"	4.4
RW 1 (80 gpm)	1160 gpm	12.6	12"	3.3

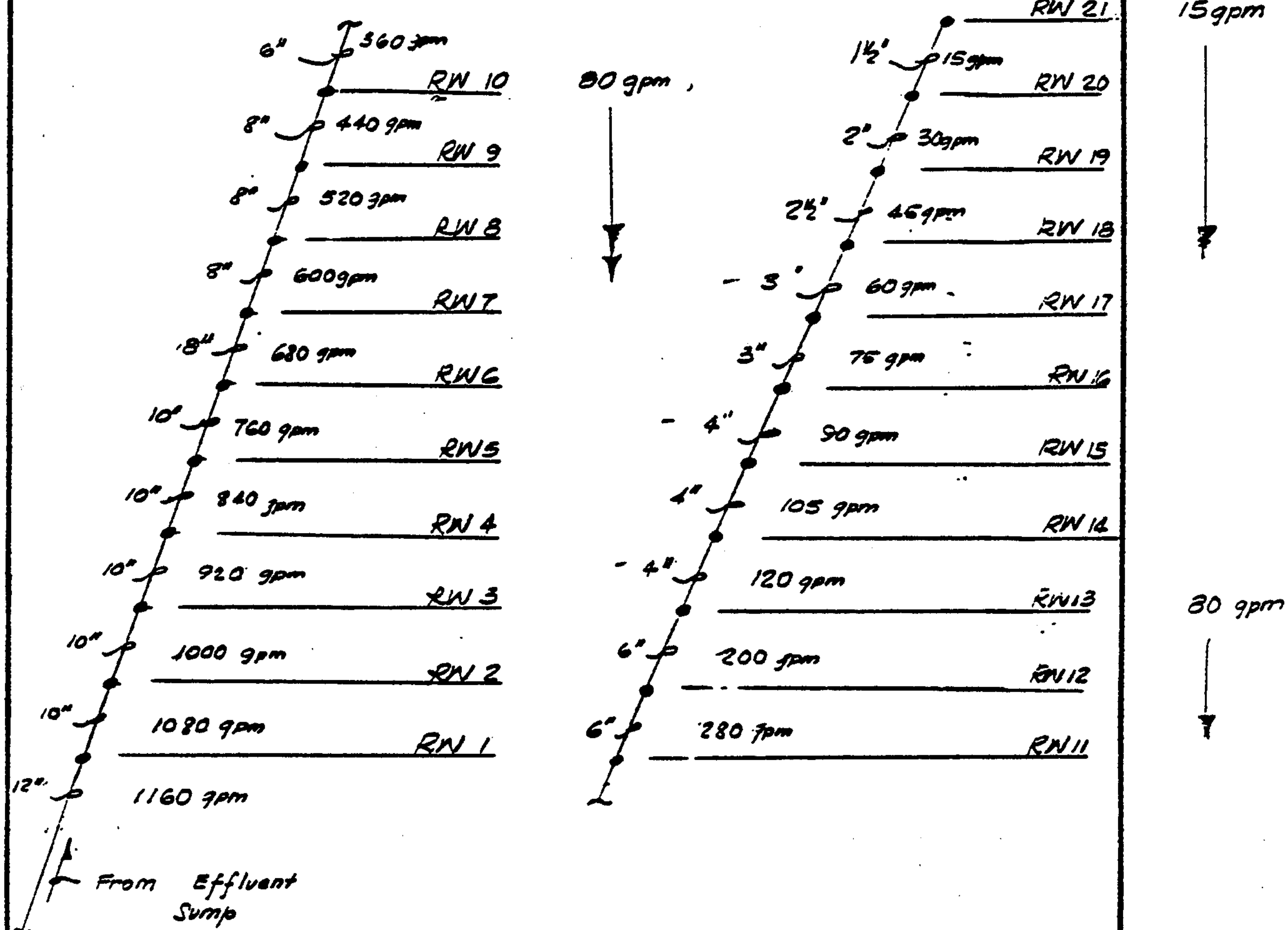
Flow through the recharge piping will vary

Check for: (a) Qmin = 500 gpm
10" ⟶ Vel = 2.0 fps
12" ⟶ Vel = 1.4 fps

(b) Q max = 1500 gpm
10" ⟶ Vel. = 6.1 fps > 5 fps
12" ⟶ Vel. = 4.3 fps

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA . PN 37 NW Boundary		SHEET NO. 5	OF 8
ITEM Recharge Water Pipe		BY MCB	DATE 12/83
		CHKD. BY LLT	DATE

(RW w/ approx. average flows)



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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA PN 37 NW Boundary		SHEET NO. 6 OF 8
ITEM Sizing Discharge Water Piping		BY HCB DATE
		CHKD. BY LLT DATE

(DW w/ approximate average flows)

Well	Q(gpm)	Pipe dia. for V=3fps	Use pipe dia.	Vel. (fps)
DW 15 (25 gpm)	25 gpm	1.9	2"	2.6
DW 14 (25 gpm)	50 gpm	2.6	2½"	3.3
DW 13 (25 gpm)	75 gpm	3.2	3"	3.4
DW 12 (25 gpm)	100 gpm	3.7	4"	2.6
DW 11 (25 gpm)	125 gpm	4.1	4"	3.2
DW 10 (100 gpm)	225 gpm	5.5	6"	2.6
DW 9 (100 gpm)	325 gpm	6.7	6"	3.7
DW 8 (100 gpm)	425 gpm	7.6	8"	2.7
DW 7 (100 gpm)	525 gpm	8.5	8"	3.6
DW 6 (100 gpm)	625 gpm	9.2	8"	4.0
DW 5 (100 gpm)	725 gpm	9.9	10"	3.0
DW 4 (100 gpm)	825 gpm	10.6	10"	3.4

OMAHA DISTRICT	COMPUTATION SHEET		CORPS OF ENGINEERS
PROJECT RMA PN 37 NW Boundary		SHEET NO. 7	OF 8
ITEM Sizing Discharge Water Piping (Cont)		BY HWB	DATE
		CHKD. BY LLT	DATE

Well	Q(gpm)	Pipe dia for V = 3 fps	Use pipe dia.	Vel. (fps)
DW 3 (100 gpm)	925 gpm	11.2	10"	3.8
DW 2 (100 gpm)	1025 gpm	11.8	10"	4.2
DW 1 (100 gpm)	1125 gpm	12.4	12"	3.1

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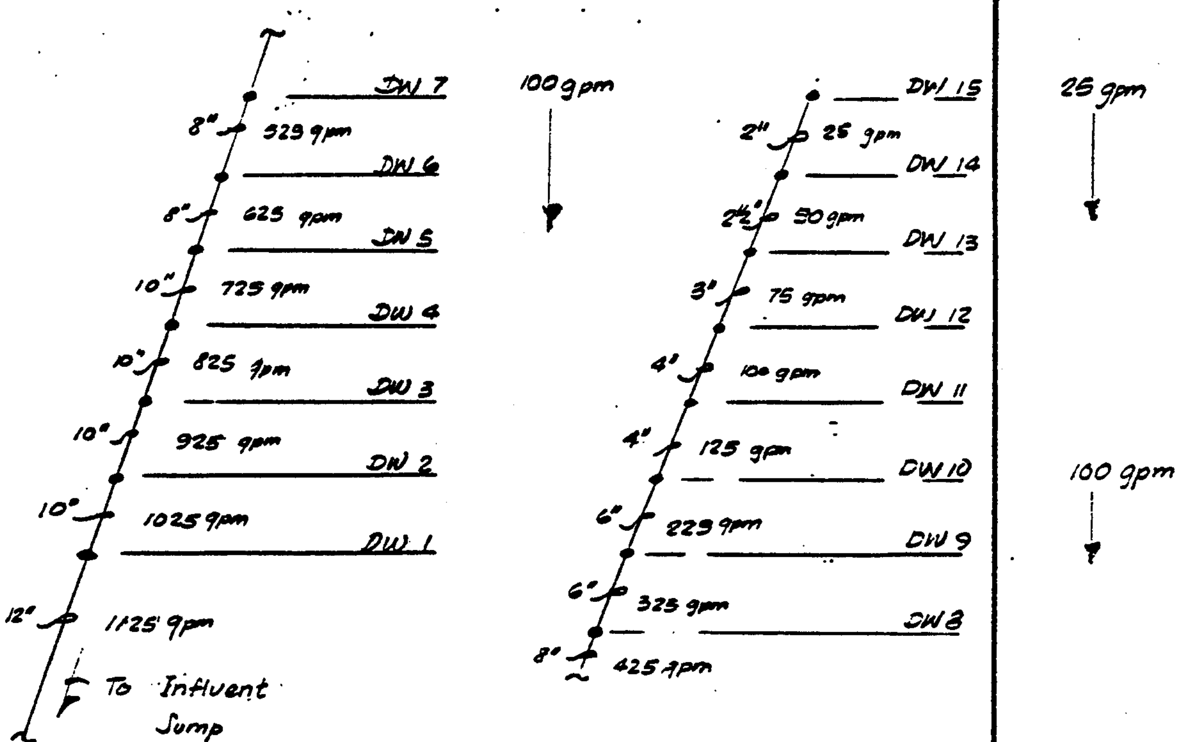
OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA PN 37 NW Boundary		SHEET NO. 8 OF 8
ITEM Discharge Water Pipe		BY MCB DATE 12/83
		CHKD. BY LLT DATE



OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA PN 37 — NW Boundary		SHEET NO. 1 OF 20
ITEM Pumps from Effluent Sump to Recharge Wells	BY MCB	DATE 12/83
	CHKD. BY LLT	DATE

- System Capacity = 1500 gpm

- Effluent Pumping System will consist of 4 vertical sump pumps with only three operating at peak flows. One pump will serve as a standby. The pumps will operate in parallel --

- Pump design.

(a) Pipe Friction Losses
(Effluent Sump to Recharge Wells)

1. Recharge Water Pipe to Tee (for ea. well)

2. Tee to Recharge Well

3. Effluent Sump Piping (Pump to Recharge Water Pipe)

(b) Difference in elevation + Pipe Friction Losses = Head above ground (HAG)

(c) Static water level + HAG = Field Pumping Head (FPH)

(d) Column Losses + FPH = Total Dynamic Head (TDH)

(e) Obtain HP required

Design for the maximum estimated flows :

OMAHA DISTRICT | COMPUTATION SHEET | CORPS OF ENGINEERS

PROJECT		SHEET NO. 2	OF 20
ITEM Pipe friction losses through Recharge Water Pipe (header) (1)		BY MCB	DATE 12/82
		CHKD. BY LLT	DATE

Q_{max} = 1500 gpm

RW 1→13 = 103 gpm

RW 14→21 = 20 gpm

$$h_L = \frac{10.46}{d^{4.87}}\left(\frac{Q}{140}\right)^{1.85}(L)$$

Q = gpm
d = inches
L = feet
C = 140 (plastic)

	Q (gpm)	dia. (in.)	Length (ft)	h_L ft	psi
	1500 gpm	12"	960'	4.48	1.94
RW 1	1397 gpm	10"	80'	0.80	0.35
RW 2	1294 gpm	10"	80'	0.69	0.30
RW 3	1191 gpm	10"	80'	0.59	0.26
RW 4	1088 gpm	10"	80'	0.50	0.22
RW 5	985 gpm	10"	80'	0.42	0.18
RW 6	882 gpm	8"	80'	1.01	0.44
RW 7	779 gpm	8"	80	0.80	0.35
RW 8	676 gpm	8"	80'	0.62	0.27
RW 9	573 gpm	8"	80'	0.45	0.19
RW 10	470 gpm	6"	80'	1.28	0.55
RW 11	367 gpm	6"	80'	0.81	0.35
RW 12	264 gpm	6"	80'	0.44	0.19

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT	SHEET NO. 3 OF 20	
ITEM	BY MCB	DATE 12/82
Q = 1500 gpm	CHKD. BY LLT	DATE

	Q (gpm)	dia. (in.)	Length (ft)	h_L ft.	psi
RW 13	161 gpm	4"	80'	1.27	0.55
RW 14	141 gpm	4"	150'	1.86	0.81
RW 15	121 gpm	4"	150'	1.4	0.61
RW 16	101 gpm	3"	150'	4.07	1.76
RW 17	81 gpm	3"	160'	2.71	1.17
RW 18	61 gpm	2½"	150'	3.9	1.69
RW 19	41 gpm	2"	150'	5.5	2.38
RW 20	21 gpm	1½"	150'	6.5	2.81
RW 21				40 ft	

Use 40 ft

Fittings through header ≈ 3 ft → 5

45 ft

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT		SHEET NO. 4. OF 20
ITEM		BY HCB / DATE
		CHKD. BY LLT / DATE

Q_{ave} = 1160 gpm
(RW 1 → RW 13 = 80 gpm
RW 14 → RW 21 = 15 gpm)

$$h_L = \frac{10.46}{d^{4.87}} \left(\frac{Q}{140}\right)^{1.85} (L)$$

	Q (gpm)	dia. (in.)	Length (ft)	h_L ft	psi
	1160 gpm	12"	960'	2.8	1.21
RW 1 (80 gpm)	1080 gpm	10"	80'	0.5	0.22
RW 2 (80 gpm)	1000 gpm	10"	80'	0.43	0.19
RW 3 (80 gpm)	920 gpm	10"	80'	0.37	0.16
RW 4 (80 gpm)	840 gpm	10"	80'	0.31	0.13
RW 5 (80 gpm)	760 gpm	10"	80'	0.26	0.11
RW 6 (80 gpm)	680 gpm	8"	80'	0.62	0.27
RW 7 (80 gpm)	600 gpm	8"	80'	0.49	0.21
RW 8 (80 gpm)	520 gpm	8"	80'	0.38	0.16
RW 9 (80 gpm)	440 gpm	8"	80'	0.28	0.12
RW 10 (80 gpm)	360 gpm	6"	80'	0.78	0.34
RW 11 (80 gpm)	280 gpm	6"	80'	0.49	0.21
RW 12 (80 gpm)	200 gpm	6"	80'	0.26	0.11

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT		SHEET NO. 5 OF 20
ITEM		BY UCB DATE
		CHKD. BY LLT DATE

	Q (gpm)	dia (in)	Length (ft)	h_L (ft)	(psi)
RW13 (20 gpm)	120 gpm	4"	80'	0.74	0.32
RW 14 (15 gpm)	105 gpm	4"	150'	1.08	0.47
RW 15 (15 gpm)	90 gpm	4"	150'	0.81	0.35
RW 16 (15 gpm)	75 gpm	3"	150'	2.35	1.02
RW 17 (15 gpm)	60 gpm	3"	150'	1.55	0.67
RW 18 (15 gpm)	45 gpm	2½	150'	2.22	0.96
RW 19 (15 gpm)	30 gpm	2	150'	3.10	1.34
RW 20 (15 gpm)	15 gpm	1½"	150'	3.5	1.51
RW 21 (15 gpm)				23.	
				$\Sigma h_L = 23.32$	10.1 psi

Fittings through header = 5 ft

Use 30 ft

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT		SHEET NO. 6 OF 20
ITEM		BY HCB DATE 12/83
		CHKD. BY LLT DATE

$Q_T = 1014$ gpm

RW 1→RW 13 = 70 gpm
RW 14–RW 21 = 13 gpm

$$h_L = \frac{10.46}{d^{4.87}} \left(\frac{Q}{140}\right)^{1.85} (L)$$

	Q (gpm)	dia (in)	Length (ft)	h_L ft	psi
	1014 gpm	12"	960'	2.17	0.94
RW 1 (70 gpm)	944 gpm	10"	80'	0.39	0.17
RW 2	874 gpm	10"	80'	0.33	0.14
RW 3	804 gpm	10"	80'	0.29	0.12
RW 4	734 gpm	10"	80'	0.24	0.10
RW 5	664 gpm	10"	80'	0.20	0.09
RW 6	594 gpm	8"	80'	0.48	0.21
RW 7	524 gpm	8"	80'	0.38	0.17
RW 8	454 gpm	8"	80'	0.29	0.13
RW 9	384 gpm	8"	80'	0.22	0.09
RW 10	314 gpm	6"	80'	0.61	0.26
RW 11	244 gpm	6"	80'	0.38	0.16
RW 12	174 gpm	6"	80'	0.20	0.09

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT		SHEET NO. 7 OF 20
ITEM		BY MCB DATE 12/83
		CHKD. BY LLT DATE

	Q (gpm)	dia. (in)	Length (ft)	h_L ft	psi
RW 13	104 gpm	4"	80'	0.56	0.24
RW 14	91 gpm	4"	150'	0.83	0.36
RW 15	78 gpm	4"	150'	0.62	0.27
RW 16	65 gpm	3"	150'	1.80	0.78
RW 17	52 gpm	3"	150'	1.19	0.52
RW 18	39 gpm	2½	150'	1.70	0.74
RW 19	26 gpm	2"	150'	2.38	1.03
RW 20	13 gpm	1½"	150'	2.68	1.16
RW 21				Σ_{h_L} = 17.94	= 7.8 psi

Fittings through header ≃ 4 ft

Use 22 ft

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Q=500
1/2

Change

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT	SHEET NO. 8	OF 20
ITEM Header Piping Friction Loss Q_{min} = 500 gpm	BY MCB DATE 12/83	CHKD. BY LLT DATE

Q=500 gpm

(One pump oper.)

$$h_L = \frac{10.46}{d^{4.87}}\left(\frac{Q}{140}\right)^{1.85}(L)$$

For Wells 1-13 Q_w = 34 gpm (Q_{des} 80 gpm)

" " 14-21 Q_w = 7.25 gpm (Q_{des} = 15 gpm)

	Q (gpm)	diam (in)	Length	h_L ft	psi
	500 gpm	12"	960'	0.59	0.25
RW 1	466 gpm	10"	80'	0.10	0.05
RW 2	432 gpm	10"	80'	0.09	0.04
RW 3	398 gpm	10"	80'	0.08	0.03
RW 4	364 gpm	10"	80'	0.07	0.03
RW 5	330 gpm	10"	80'	0.06	0.02
RW 6	296 gpm	8"	80'	0.13	0.06
RW 7	262 gpm	8"	80'	0.11	0.05
RW 8	228 gpm	8"	80'	0.08	0.04
RW 9	194 gpm	8"	80'	0.06	0.03
RW 10	160 gpm	6"	80	0.25	0.11
RW 11	126 gpm	6"	80'	0.11	0.05
RW 12	92 gpm	6"	80	0.06	0.03
RW 13	58 gpm	4"	80'	0.19	0.08
RW 14					

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Q=500/1/2

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT		SHEET NO. 9 OF 20
ITEM		BY HCB DATE
		CHKD. BY LLT DATE

RW 15	50.8 gpm	4"	150'	0.28	0.12
RW 16	43.5	4"	150'	0.21	0.09
RW 17	36.3	3"	150'	0.65	0.27
RW 18	29.0	3"	150	0.40	0.18
RW 19	21.8	$2\frac{1}{2}$	150	0.58	0.25
RW 20	14.5	2"	150	0.85	0.35
RW 21	7.25	$1\frac{1}{2}$"	150	0.91	0.39

$\Sigma h_L =$ 5.8 ft   2.5 psi

≈ 6 ft

Fittings through header, est. 2 ft

∴ use 10 ft

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT		SHEET NO. 10 OF 20
ITEM ② Friction h_L from tee to Rech. Well (through valve pit)		BY MCB — DATE 12/82
		CHKD. BY LLT — DATE

	Q_T	h_L RW-1 through RW-13		h_L RW 14 — RW-21	
I	1500 gpm	8 ft		8 ft	Use
II	1160 gpm	5 ft		6 ft	Use
III	1014 gpm	5 ft	Use	4 ft	
IV	500 gpm	4 ft	Use	3 ft	

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT		SHEET NO. 11	OF 20
ITEM Friction h_L from tee to well		BY MCB	DATE 12/82
		CHKD. BY LLT	DATE

(through valve pit)

For RW-1 through RW-13

$Q_T = 1500$ gpm

$Q_{max} = 103$ gpm

(a) 3' pipe

(1) ± 20 L.F; plastic $h_L = 0.56$ ft

(2) ± 20 L.F; metallic $h_L = 0.75$ ft

(b) 3" Water Meter ⟶ $h_L = 2.8$ ft

(c) Ball Valve ⟶ $h_L = 0.5$ ft

(d) Equivalent lengths for other fittings

Gate Valve	—	2.3 ft
Tees	—	10.5 ft
90° Bends (5)	—	45.0 ft
		57.8 ft ; use 65 ft

$$h_L = \frac{10.46}{3^{4.87}} \left(\frac{108}{120}\right)^{1.85} (65) = 2.5 \text{ ft}$$

$$\Sigma h_L = 0.56 + 0.75 + 2.8 + 0.5 + 2.5$$

$$\Sigma h_L = 7.11 \text{ ft} \approx \underline{8 \text{ ft}}$$

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS

PROJECT	SHEET NO. 12 OF 20	
ITEM Frict. h_L from tee to well (through valve pit)	BY MCB	DATE 12/83
	CHKD. BY LLT	DATE

For RW 1 ⟶ RW 13

$Q_T = 1160$ gpm

II $Q_{ave} = 80$ gpm

(a) 3" Pipe

(1) ± 20 L.F., plastic $h_L = 0.35'$

(2) ± 20 L.F., metallic $h_L = 0.47'$

(b) 3" Water Meter $h_L = 2.5$ ft

(c) 3" Ball Valve $h_L = 0.5$ ft

(d) Equiv. Lengths $= 65$ ft

$\therefore h_L = 1.15$ ft

$\Sigma_{Tot} = 0.35' + 0.47' + 2.5 + 0.5' + 1.15' = 4.97$

Use 5 ft

III $Q_T = 1014$ gpm (RW 1 ⟶ RW 13)

$Q = 70$ gpm

(a) 3" pipe

(1) $h_L = 0.28'$

(2) $h_L = 0.40'$

(b) Wat. Meter $h_L = 2.3$ ft

(c) Ball Valve $h_L = 0.4$ ft

(d) Eq. Lengths $h_L = 1.2$ ft

$\Sigma = 4.6 \rightarrow$ Use 5 ft

IV $Q = 500$ gpm

$Q = 34$ gpm

Use 4 ft

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT	SHEET NO. 13 OF 20	
ITEM Friction h_L from tee to well	BY MCB	DATE 12/83
	CHKD. BY LLT	DATE

(through valve pit)

(For RW 14 through RW 21)

$Q_T = 1500$ gpm

I $Q_{max} \doteq 20$ gpm

(a) 1½" Pipe

(1) < 20 L.F., plastic $h_L = 0.79$ ft

(2) ≥ 20 L.F., metallic $h_L = 1.06$ ft

(b) 1½" Water Meter ⟶ $h_L = 2$ ft

(c) Ball Valve ⟶ $h_L = 0.5$ ft

(d) Equivalent Length on other fittings

Gate Valve	1.2 ft
Tees (2)	10.5 ft
90° Bend (3)	37.0 ft
	48.7' ; 55 ft

$$h_L = \frac{10.46}{1.5^{4.87}}\left(\frac{20}{120}\right)^{1.85}(55) = 2.90 \text{ ft}$$

$$\Sigma h_L = 0.79 + 1.06 + 2.0 + 0.5 + 2.90 \text{ ft}$$

$$= 7.25 \text{ ft} = \underline{8 \text{ ft}}$$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT		SHEET NO. 14 OF 20	
ITEM Friction h_L from tee to well (through valve pit)		BY MCB	DATE 12/93
		CHKD. BY LLT	DATE

For RW 14 - 21

Q_T = 11.60 gpm

I Q_{ave} = 15 gpm

(a) 1½" Pipe

(1) < 20 L.F plastic h_L = 0.47 ft 0.26

(2) < 20 LF metallic h_L = 0.62 ft

(b) 1½" Wat. Meter = h_L = 2 ft 1.5

(c) 1½ Ball valve h_L = 0.5 ft .4

(d) Equiv. Length on other fittings

Gate Valve	1.2 ft
Tees (2)	10.5 ft
90° Bends (3)	37.0 ft
	48.7'; Use 55 ft

$$h_L = \frac{10.46}{1.5^{4.87}} \left(\frac{15}{120}\right)^{1.85} (55') = 1.7 \text{ ft}$$

$$\Sigma h_L = 0.47' + 0.62' + 2.0' + 0.5' + 1.7 \text{ ft}$$

$$= 5.29 \text{ ft} \quad ; \text{Use } 6 \text{ ft}$$

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PROJECT	SHEET No. 15 OF 20	
ITEM Friction h_L from tee to well (through valve pit)	BY MCB	DATE 12/83
	CHKD. BY LLT	DATE

For RW 14 → RW 21

III Q_T = 1014 gpm

Q = 13 gpm

(a) 1½" Pipe

(1) : h_L = 0.26 ft

(2) h_L = 0.35 ft

(b) 1.5 ft

(c) 0.4 ft

(d) 1 ft

Σ = 3.5 Use 4 ft

IV Q_T = 500 gpm Q = 6.4 gpm

Use 3 ft

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT		SHEET NO. 16 OF 20	
ITEM ③ Pipe friction losses through Effluent sump piping		BY MCB	DATE
		CHKD. BY	DATE

$K\frac{V^2}{2g} = h_L$

Pipe Length @ Effluent Sump

$= 8 + 3 + 3 + 10 \Rightarrow 24$ ft $\rightarrow h_L = 0.57$ ft @ 500 gpm

6" → Pressure sust. & check valve

K = 10 — h_L = 5.0 ft

6" → 90° Bend (2) → K = 0.9 — h_L = 0.91 ft

6' → 90° Bend or tee → K = 1.8 — h_L = 0.91 ft

12" → Branch tee (3) → K = 0.6 — h_L = 0.52 ft

6" → Gate Valve → K = 0.19 — h_L = 0.2 ft

Σh_L = 8.11 ft ≃ 9 ft

Use 10 ft h_L for all ①

Velocities

6" pipe @ 500 gpm = 5.7 fps

12" pipe @ 1500 gpm = 4.3 fps
@ 1225 gpm = 3.5 "
@ 1000 gpm = 2.84 "
@ 500 gpm = 1.4 "

MRO FORM 1550
1 OCT 72

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT		SHEET NO. 17 OF 20	
ITEM Total Pipe Friction Losses		BY MCB	DATE
		CHKD. BY	DATE

TOTAL FRICTION LOSSES (a)

Q_T	Header (1)	Valve Pit (2)	Effluent Jump (3)	TOTAL
1500 gpm	45	8'	10'	63 ft
1160 gpm	30	6'	10'	46 ft
1014 gpm	22	5'	10'	37 ft
500 gpm	10 –	4'	10'	24 ft

MRO FORM 1 OCT 72 1550

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT		SHEET NO. 18 OF 20	
ITEM Effluent Sump Pumps		BY MCB	DATE 12/83
		CHKD. BY LLT	DATE

Q = 500 gpm for each pump

1750 RPM

(1) Static Water Level (SWL) = (min. water level up to ℄ of pump discharge)

= 7 ft

(2) Head Above Ground (HAG)

(a) Diff. in elev. = 5134 − 5128 = 6 ft

(The highest ground level will be @ farthest recharge well; RW-21)

(b) Friction Losses

@ Q = 1500 gpm = 63 ft

∴ Head Above Ground = 63 ft + 6 ft ⇒ 69 ft

; use 70 ft

(3) Field Pumping Head (FPH)

= (SWL) + (HAG) = 7 ft + 70 ft ⇒ 77 ft

(4) Length of pump column = 15 ft

(5) Column friction head = ± 3 ft

MRO FORM 1550
1 OCT 72

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA NW Boundary		SHEET NO. 19 OF 20
ITEM Effluent Sump Pumps	BY MCB	DATE 12/83
	CHKD. BY LLT	DATE

(8) Total Dynamic Head (TDH)

= 77 ft + 3 ft → 80 ft

+ 20 ft control valve

TDH = 100 ft

(9) Calculate pump HP

$$H.P. = \frac{(100\ ft)(500\ gpm)}{(3960)(0.70)} = 18.1\ HP$$

Use 20 HP pump

Pump Discharge Line = 6 ft

The pressure sustaining valve at the pump discharge line will be set at the system head required for Q_T = 1500 gpm. Each of the three parallel operating pumps will discharge 500 gpm.

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1 OCT 72

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT		SHEET NO. 20 OF 20	
ITEM		BY	DATE
		CHKD. BY	DATE

Check for NPSH

NPSH ⇒ Barom. Press. (ft) − Total Suction Lift (ft) − Vapor Pressure of liq. (ft)

Elev. 5130 Barom. Press. = 27.8 ft

− Vapor Pressure @ 85°F ⇒ 1.4 ft

− Total Suction Lift ⇒ 12 ft + 1.5 ft ⇒ 13.5 ft

∴ NPSH available ⇒ 27.8' − 1.4' − 13.5
⇒ 12.9 ft

NPSH (maximum from manuf.) = 9 ft

∴ 12.9 ft − 9 ft = 3.9 ft available in excess of that req'd.

MRO FORM 1550
1 OCT 72

OMAHA DISTRICT — COMPUTATION SHEET — CORPS OF ENGINEERS

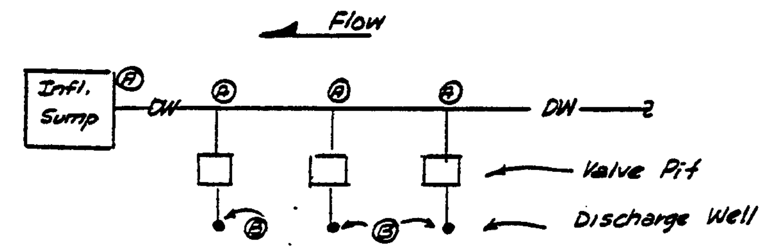
PROJECT KMA PN 37 N W Boundary — SHEET NO. 1 OF 7

ITEM Discharge Well Pump Capacities Q_{max} = 1500 gpm — BY MCB DATE 1/83 — CHKD. BY LLT DATE

See computation Sheet

	②	③	②	④&⑤	⑥	⑦	⑦			
	HEADER		WELL PIPING		PUMP COLUMN					
Well	Δ Elev (ft)	Frict (ft)	Δ Elev. (ft)	Frict (ft)	(F & CKV.) (ft)	Static (ft)	Drawd (ft)	Σh_L (ft)	Valve (ft)	TOTAL HEAD (ft)
DW1	5.5	4.7	Neg	17	6	38.5	7	78.7	20	100
DW2	5.7	5.7	Neg	17	6	35.5	7	76.9	20	100
DW3	5.2	6.5	0.2	17	6	38.5	7	80.4	20	100
DW4	5.2	7.1	0.5	17	6	41	7	83.8	20	105
DW5	7.2	7.6	Neg	17	6	40	7	84.8	20	105
DW6	9.4	8.6	Neg	17	6	37	7	85.0	20	105
DW7	9.4	9.5	Neg	17	6	36	7	85	20	105
DW8	9.0	10.0	Neg	17	6	36	7	85	20	105
DW9	7.0	11.3	Neg	17	6	36	7	84.8	20	105
DW10	5.0	12.0	Neg	17	6	39	7	86	20	105
DW11	3.4	14.0	Neg	4.5	4	41.5	5	72.4	20	95
DW12	-0.5	16.3	0.5	4.6	4	38.5	5	68.3	20	95
DW13	4.0	21.8	1.0	4.5	4	33	5	73.3	20	95
DW14	4.0	28.1	Neg	4.5	4	40	5	85.16	20	110
DW15	3.3	33.3	0.5	4.5	4	40	5	90.6	20	110

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA PN 37 NW Boundary		SHEET NO. 2 OF 7
ITEM Discharge Wells Losses due to differences in elevation		BY MCB DATE 1/83 CHKD. BY LLT DATE



HEADER PIPING | WELL PIPING A → B

Well	Ground Elev @ A	Δ Elev.	Comm. for ea. pt.	Ground Elev. @ B	ΔElev: A≠B	Add (L.A)
Sump	5130.0					
		+5.5	+5.5	5124.5	0	Neg
DW 1	5124.5					
		+0.2	+5.7	5124.3	0	Neg.
DW 2	5124.3					
		-0.5	+5.2	5124.7	+0.1	+0.2
DW 3	5124.8					
		0	+5.2	5126.5	+0.2	+0.5
DW 4	5124.8					
		+2.0	+7.2	5125.4	- 0.7	Neg.
DW 5	5124.7					
		+2.2	+9.4	5122.8	-0.3	Neg.
DW 6	5122.8					
		0	+9.4	5123.2	-0.7	Neg.
DW 7	5122.5					
		-0.5	+8.9 ≈ 9	5123.8	-0.8	Neg.
DW 8	5123.0					
		-2.0	+6.9 ≈ 7	5125.5	-0.5	Neg.
DW 9	5125.0					
		-2.0	+4.9 ~ 5	5127.5	-0.5	Neg.
DW 10	5127.0					
		-1.5	+3.4	5129.0	-0.5	Neg.
DW 11	5128.5					
		-5.2	-1.8 use -.5	5133.5	+0.2	+0.5
DW 12	5133.7					
		+5.7	+3.9 ≈ 4	5128.5	+0.5	+1.0
DW 13	5128.0 33.4					
		0	+3.9 ≈ 4	5133.1	0	Neg.
DW 14	5133.1					
		-0.6	+3.9 ≈ 4	5133.3	+0.4	+0.5
DW 15	5133.7					

Very small add only the (+)

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(−) Upstream pipe elev. is higher than downstream

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS

PROJECT RMA PN 37 NW Boundary | SHEET NO. 3 OF 7

ITEM Discharge Wells Losses due to Pipe Friction @ header | BY HCB | DATE 1/83 | CHKD. BY LLT | DATE

$Q_{T_{max}}$ = 1500 gpm

Q = 135 gpm (DW 1 → DW 10)
Q = 30 gpm (DW 11 → DW 15)

$$h_L = \frac{10.46}{d^{4.87}} \left(\frac{Q}{140}\right)^{1.85} (L)$$

Well	Q (gpm)	dia (in)	Length (ft)	h_L (ft)	Σh_L to sump
DW 15	30 gpm	2"	250'	5.17	33.3
DW 14	60 gpm	2½"	250'	6.29	28.1
DW 13	90 gpm	3"	250'	5.48	21.8
DW 12	120 gpm	4"	250'	2.30	16.3
DW 11	150 gpm	4"	150	2.08	14.0
DW 10	285 gpm	6"	100	0.63	12.0
DW 9	420 gpm	6"	100	1.30	11.3
DW 8	555 gpm	8"	100	0.53	10.0
DW 7	690 gpm	8"	100	0.80	9.5
DW 6	825 gpm	8"	100	1.11	8.7
DW 5	960 gpm	10"	100	0.50	7.6
DW 4	1095 gpm	10"	100	0.63	7.1
DW 3	1230 gpm	10"	100	0.79	6.5
DW 2	1365 gpm	10"	100	0.95	5.7
DW 1	1500 gpm	12"	1010	4.72	4.7

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA DN 37 NW Boundary		SHEET NO. 4 OF 7	
ITEM Friction losses from well to connection w/ header (DW 1 → DW 10)		BY UCB	DATE
		CHKD. BY LLT	DATE

$Q_{T_{max}}$ = 1500 gpm

<u>Q_{max} = 135 gpm</u> (DW 1 → DW 10)

$Vel._{3"}$ = 6.13 fps

(1) Horizontal Piping (3")

(a) L = 20 ft (plastic C=140) —— h_L = 0.93 ft

(b) L = 20 ft (metallic C=120) —— h_L = 1.23 ft

(2) 3" Flow meter (Rockwell) —— h_L = 5.8 ft

(3) 3" Sust & Check valve —— h_L = 5.0 ft

(4) <u>Equivalent Lengths</u> (3")

(a)	90° Bend (4)	@ 9' ea.	=	36'
(b)	Gate Valve	@ 3' ea.	=	3'
(c)	Tee	@ 10' ea	=	10'
(d)	Inlet	@ 0.67' ea	=	0.67'
(e)	Increaser			

Σ_{EL} = 50 ft
Use 55 ft

$$h_L = \frac{10.46}{3^{4.87}} \left(\frac{135}{120}\right)^{1.85} (55') \Rightarrow 3.4' \simeq 3.5$$

Σh_L = 0.93' + 1.23' + 5.8' + 5.0' + 3.5' =

Σh_L = 16.56 ∴ $\boxed{\text{Use 17 ft}}$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA PN 37 NW Boundary		SHEET NO. 5 OF 7	
ITEM Friction losses from well to connection w/ header (DW 11 → DW 15)		BY MCB	DATE
		CHKD. BY LLT	DATE

$\boxed{Q_{Tmax} = 1500 \text{ gpm}}$

$Q_{max} = 30$ gpm (DW 11 → DW 15)

$Vel._{2''} = 3.06$ fps

(1) Horizontal Piping (2")

(a) L = 20 ft (plastic) C=140 — h_L = 0.42 ft

(b) L = 20 ft (metallic) C=120 — h_L = 0.60 ft

(2) 2" Flow meter (Rockwell) — h_L = 1 ft

(3) 2" Press Sust. & Ck. Valve — h_L = 0.5 ft

(4) Equivalent Lengths (2")

(a) 90° Bends (4) @

(b) Gate Valve (1) @

(c) Tee 1 @

(d) Inlet · @

(e) Inc.

Σ_{EL} =

Use 45 ft

$$h_L = \frac{10.46}{2^{4.87}} \left(\frac{30}{120}\right)^{1.85} (45) = 1.24'$$

Use h_L = 1.5 ft

Σh_L = 0.42' + 0.60' + 1' + 0.5' + 1.5'

Σh_L = 4.1 → $\boxed{\text{Use } 4.5 \text{ ft}}$

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA PN 37 NW Boundary	SHEET NO. 6 OF 7	
ITEM Discharge Well Pump Column Friction Losses	BY HCB	DATE
	CHKD. BY LLT	DATE

Well	Qmax	Column Length	Column h_L	Check Valve h_L	h_{L_T}
DW 1	135gpm	60 ft	±1 ft	5 ft	6 ft
DW 2	↓	57 ft	↓	↓	6 ft
DW 3		60 ft			6 ft
DW 4		63 ft			6 ft
DW 5		60 ft			6 ft
DW 6		57 ft			6 ft
DW 7		57 ft			6 ft
DW 8		57 ft			6 ft
DW 9		55 ft			6 ft
DW 10		53 ft			6 ft
DW 11	30 gpm	54 ft	1.5 ft	2.5 ft	4 ft
DW 12	↓	51 ft	↓	↓	4 ft
DW 13		49 ft			4 ft
DW 14		55 ft			4 ft
DW 15		55 ft			4 ft

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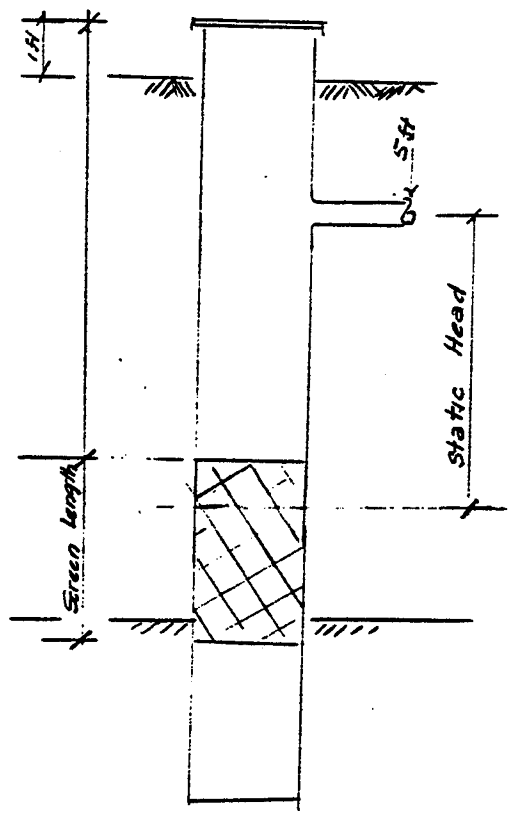
1 OCT 72

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA PN 37 NW Boundary	SHEET NO. 7	OF 7
ITEM Static Heads and Drawdown for Disch Wells	BY MCB	DATE 1/83
	CHKD. BY	DATE



Well	Static Length
DW 1	38.5 ft
DW 2	35.5 ft
DW 3	38.5 ft
DW 4	41 ft
DW 5	40 ft
DW 6	37 ft
DW 7	36 ft
DW 8	36 ft
DW 9	36 ft
DW 10	39 ft
DW 11	41.5 ft
DW 12	38.5 ft
DW 13	33.0 ft
DW 14	41 ft
DW 15	41 ft

Static Length = (Riser Pipe − 6ft) + ½ Screen Length

Drawdown Use 7 feet (DW 1 → DW 10)
Use 5 feet - (DW 11 → DW 15)

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA	PN 37 NW Boundary	SHEET NO. 1 OF 7
ITEM Discharge Well Pump Capacities Qave = 1125 gpm	BY HCB	DATE 1/83
	CHKD. BY	DATE

See Computation Sheet →

	②	③	②	④⑤	⑥	⑦	⑦			
	HEADER		WELL PIPING		PUMP COLUMN					
Well	Δ Elev. (ft)	Frict. (ft)	Δ Elev. (ft)	Frict (ft)	(F & CV) (ft)	Static (ft)	Drawd. (ft)	Σ h_L (ft)	Valve (ft)	Total Head (ft)
DW 1	5.5	2.8	Neg	9	5	43	7	72.3	20	95
DW 2	5.7	3.3	Neg	9	5	40	7	70.0	20	95
DW 3	5.2	3.8	0.2	9	5	43	7	73.2	20	95
DW 4	5.2	4.2	0.5	9	5	46.5	7	77.4	20	100
DW 5	7.2	4.5	Neg	9	5	44	7	76.7	20	100
DW 6	9.4	5.1	Neg	9	5	41	7	76.5	20	100
DW 7	9.4	5.6	Neg	9	5	40.5	7	76.5	20	100
DW 8	9.0	6.0	Neg	9	5	40	7	76.0	20	100
DW 9	7.0	6.8	Neg	9	5	39.5	7	74.8	20	100
DW 10	5.0	7.2	Neg	9	5	41	7	74.2	20	100
DW 11	3.4	8.7	Neg	5	3	41.5	5	66.6	20	90
DW 12	-0.5	10.3	0.5	5	3	38.5	5	61.8	20	85
DW 13	4.0	14.2	1.0	5	3	35	5	67.2	20	90
DW 14	4.0	18.7	Neg	5	3	41	5	76.7	20	100
DW 15	3.3	22.4	0.5	5	3	41.0	6	80.0	20	100

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT		SHEET NO. 3 OF 7	
ITEM Discharge Wells		BY MCB	DATE 1/83
Losses due to Pipe Friction @ header		CHKD. BY	DATE

$\boxed{Q_{T_{dw}} = 1125 \text{ gpm}}$

Q= 100 gpm (DW 1 → DW 10)

Q= 25 gpm (DW 11 → DW 15)

$$h_L = \frac{10.46}{d^{4.87}} \left(\frac{Q}{140}\right)^{1.85} (L)$$

	Q (gpm)	dia (in)	Length (ft)	h_L (ft)	Σh_L to sump
DW 15					
	25 gpm	2"	250'	3.69	22.4
DW 14					
	50 gpm	2½"	250'	4.5	18.7
DW 13					
	75 gpm	3"	250'	3.91	14.2
DW 12					
	100 gpm	4"	250	1.64	10.3
DW 11					
	125 gpm	4"	150'	1.49	8.7
DW 10					
	225 gpm	6"	100'	0.41	7.2
DW 9					
	325 gpm	6"	100'	0.81	6.8
DW 8					
	425 gpm	8"	100'	0.33	6.0
DW 7					
	525 gpm	8"	100'	0.48	5.6
DW 6					
	625 gpm	8"	100'	0.67	5.1
DW 5					
	725 gpm	10"	100'	0.30	4.5
DW 4					
	825 gpm	10"	100'	0.38	4.2
DW 3					
	925 gpm	10"	100'	0.46	3.8
DW 2					
	1025 gpm	10"	100'	0.56	3.3
DW 1					
	1125 gpm	12"	1010'	2.77	2.8

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* Assumed

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA PN 37 NW Boundary		SHEET NO. 4	OF 7
ITEM Friction losses from well to connect w/ header (DW 1 → DW 10)		BY MCB	DATE 1/83
		CHKD. BY	DATE

Q_T ave = 1125 gpm

Qave = 100 gpm (DW 1 → DW 10)

$Vel_{3''}$ = 3.27 fps

(1) Horizontal Piping (3")

(a) L = 20 ft (plastic) C=140 —— h_L = 0.53 ft

(b) L = 20 ft (metallic) C=120 —— h_L = 0.71 ft

(2) 3" Flow meter (Rockwell) —— h_L = 2.8 ft

(3) 3" Sust. & check valve —— h_L = 2.8 ft

(4) Equivalent Lengths

(a) 3"-90° Bends (4) @ 9' ea. = 36.0 ft

(b) 3" Gate Valve (1) @ 3' ea = 3.0 ft

(c) Tee (1) @ 10' ea = 10.0 ft

(d) Inlet @ 0.67 ea = 0.7

(e) Increasers

Σh_L = 50 ft

use 55 ft

$$h_L = \frac{10.46}{3^{4.87}} \left(\frac{100}{120}\right)^{1.85} (55) = 1.95'$$

use h_L = 2.0 ft

Σh_L = 0.53' + 0.71' + 2.8' + 2.8' + 2.0'

Σh_L = 8.84 ft ; $\boxed{\text{use 9 ft}}$

OMAHA DISTRICT	COMPUTATION SHEET		CORPS OF ENGINEERS
PROJECT RMA PN 37 NW Boundary		SHEET NO. 5	OF 7
ITEM Friction losses from well to connection w/ header (DW 11 → DW 15)		BY NCB	DATE 1/83
		CHKD. BY	DATE

Q_T ave = 1125 gpm

Q_{ave} = 25 gpm (DW 11 → DW 15)

$Vel_{2"}$ = 2.55 fps

(1) Horizontal Piping (2")

(a) L = 20 ft (plastic) C = 140 —— h_L = 0.3 ft

(b) L = 20 ft (metallic) C = 120 —— h_L = 0.4 ft

(2) 2" Flow meter (Rockwell) —— h_L = ± 2.0 ft

(3) 2" Pressure sust. & check valve (Clayton 51) h_L = 0.67 ft

(4) Equivalent lengths

(a)	2"-90° Bend (4)	–	8.5' ea	= 34.0 ft
(b)	2" Gate Valve (1)	–	2.0' ea	= 2.0 ft
(c)	Tee (1)	–	5.6' ea.	= 5.6 ft
(d)	Inlet		0.5	= 0.5 ft
(e)	Increasers (2)			

Σ_{EL} = 42.1 ≈ 45'

$$h_L = \frac{10.46}{(2)^{4.87}}\left(\frac{25}{120}\right)^{1.85}(45) = 0.9 \text{ ft};$$

use h_L = 1.0 ft

Σh_L = 0.3 + 0.4 + 2.0 + 0.67 + 1.0 ft

Σh_L = 4.37 ft ; $\boxed{\text{use 5 ft}}$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA PN 37 NW Boundary	SHEET NO. 6 OF 7	
ITEM Discharge Well Pump Column Friction Losses	BY MCB	DATE 1/83
	CHKD. BY	DATE

Well	Q_{ave}	Column Length	Column h_L	Check Valve h_L	h_{L_T}
DW 1	100 gpm	60 ft	± 1 ft	4 ft	5 ft
DW 2		57 ft			5 ft
DW 3		60 ft			5 ft
DW 4		63 ft			5 ft
DW 5		60 ft			5 ft
DW 6		57 ft			5 ft
DW 7		57 ft			5 ft
DW 8		57 ft			5 ft
DW 9		55 ft			5 ft
DW 10		53 ft			5 ft
DW 11	25 gpm	54 ft		2 ft	3 ft
DW 12		51 ft			3 ft
DW 13		49 ft			3 ft
DW 14		55 ft			3 ft
DW 15		65 ft			3 ft

Column Length = (Riser Pipe − 6 ft) + Screen + 5 ft (approx)

Drop Pipe : 4" (DW 1 → 10)
2" (DW 11 → 15)

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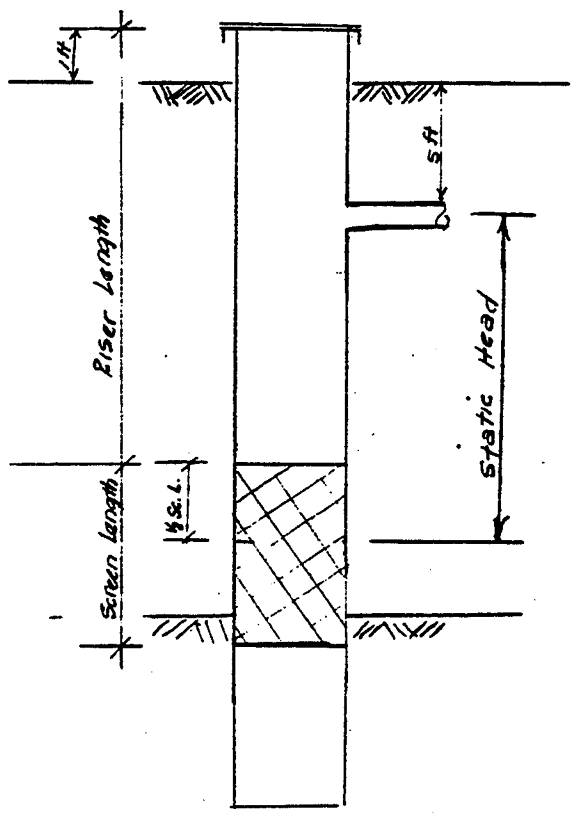
OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA PN 37 NW Boundary		SHEET NO. 7	OF 7
ITEM Static Heads and Drawdown for Disch. Wells		BY MCB	DATE 1/83
		CHKD. BY	DATE

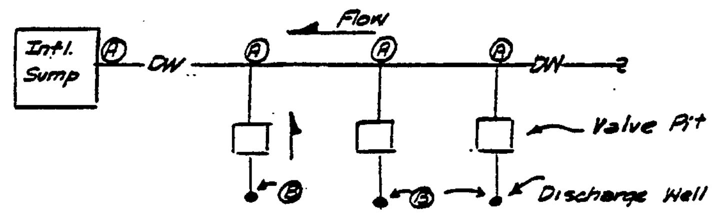


Well	Static
DW 1	43 ft
DW 2	40 ft
DW 3	43 ft
DW 4	46.5 ft
DW 5	44 ft
DW 6	41.0 ft
DW 7	40.5 ft
DW 8	40 ft
DW 9	37.5 ft
DW 10	41 ft
DW 11	41.5 ft
DW 12	38.5 ft
DW 13	35.0 ft
DW 14	41.5 ft
DW 15	41.5 ft

Static Length = (Riser Pipe Length − 6 ft) + ½ Screen Length

Drawdown : Use 7 feet (DW 1 → DW 10)
5 feet (DW 11 → DW 13)

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA PN 37 NW Boundary	SHEET NO. 2 OF 7	
ITEM Discharge Wells Losses due to diff. in elev.	BY MCB DATE 1/83	CHKD. BY DATE



HEADER PIPING				WELL PIPING Ⓐ→Ⓑ		
Well	Ground Elev. @ Ⓐ	Δ Elev.	Comm. for ea. pt.	Ground Elev. @Ⓑ	Δ Elev ÷ Ⓐ ∉ Ⓑ	Add (Lift)
Sump	5130.0					
		+5.5	+ 5.5			
DW 1	5124.5			5124.5	0	Neg
		+0.2	+ 5.7			
DW 2	5124.3			5124.3	0	Neg
		-0.5	+5.2			
DW 3	5124.8			5124.7	+0.1	+0.2
		0	+ 5.2			
DW4	5124.8			5126.5	+0.2	+ 0.5
		+2.0	+ 7.2			
DW5	5124.7			5125.4	-0.7	Neg
		+ 2.2	+9.4			
DW6	5122.5			5122.8	-0.3	Neg
		0	+9.4			
DW7	5122.5			5123.2	-0.7	Neg
		-0.5	+8.9 ≈ 9			
DW8	5123.0			5123.8	-0.8	Neg
		-2.0	+ 6.9 ~ 7			
DW 9	5125.0			5125.5	-0.5	Neg
		-2.0	+4.9 ~ 5			
DW 10	5127.0			5127.5	-0.5	Neg
		-1.5	+ 3.4			
DW 11	5128.5			5129.0	-0.5	Neg
		-5.2	- 1.8 Use (-0.5)			
DW 12	5133.7			5133.5	+0.2	+ 0.5
		+5.7	+ 3.9 ~4			
DW 13	5128.0 33.4			5128.5	+0.5	+1.0
		0	+3.9 ~4			
DW 14	5133.1			5133.1	0	Neg
		-0.6	+3.3			
DW 15	5133.7			5133.3	+0.4	+ 0.5

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(−) Upstream pipe elev. is higher than downstream

Very small add only the (+).

OMAHA DISTRICT | COMPUTATION SHEET | CORPS OF ENGINEERS

PROJECT Rocky Mnt. Arsenal - N.W. Boundry	SHEET NO. 1	OF 1	
ITEM SUMP DESIGN	BY RJC	DATE	
	CHKD. BY	DATE	

INFLUENT/EFFLUENT SUMP DESIGN

Sizing of sump based on 20 minutes between pump starts as recommended by Metcalf and Eddy, Inc. Wastewater Engineering: Collection and Pumping of Wastewater 1981 McGraw-Hill Book Company P354.

$$\forall = \frac{\theta q}{4}$$

$\forall$ = required capacity, gal

θ = minimum time in minutes of one pumping cycle = 20 minutes

q = pump capacity, gal/min. = 500

$$\forall = \frac{(20)(500)}{4} = 2500 \text{ gal} = 335 \text{ ft}^3$$

Assume a 2:1 size ratio

Therefore assume width = 10 feet
Length = 20 feet

Set minimum on/off operation of pumps at 2 feet each

Allow 3.5 feet of water for pumps in sump, 1 feet freeboard

Minimum depth for sump 12.5 feet

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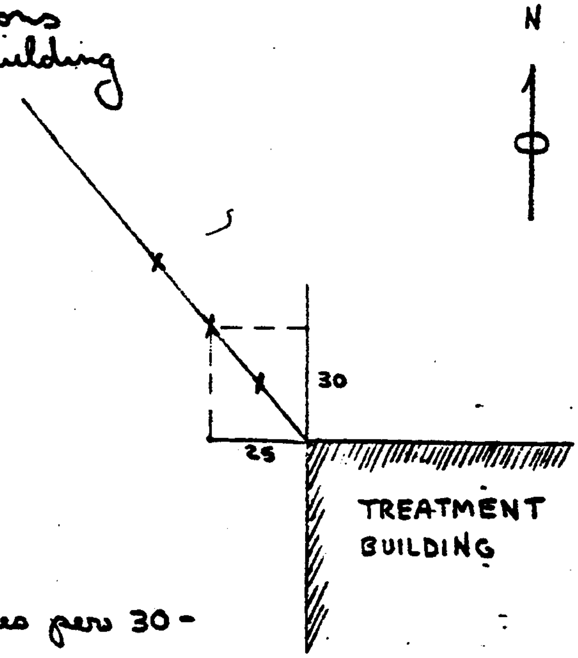
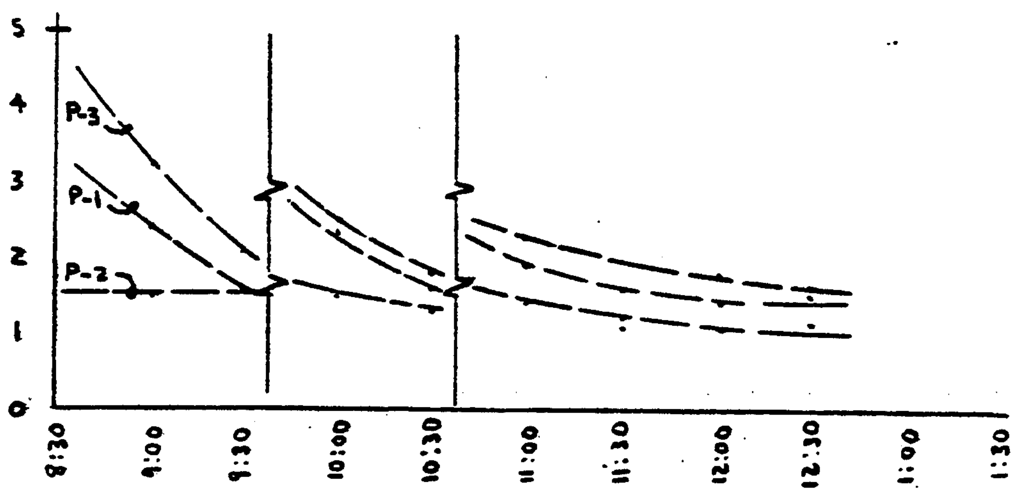
OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA PN 37 NW Boundary		SHEET NO. 1	OF 4
ITEM Domestic Water + Wastewater		BY LLJ	DATE 12/23/82
		CHKD. BY MCB	DATE 12/29/82

I. Percolation Test Results 12/3/82

Percolation test locations relative to treatment building



Water level drop in inches per 30-minute interval



Worst case extrapolation per 30-minute interval ≈ 0.85 inches. ∋ 35.3 minutes per inch. Allowable application 0.75 gallons per square foot per day

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA PN 37 NW Boundary	SHEET NO. 2 OF 4	
ITEM Domestic Water + Wastewater	BY LLJ	DATE 12/23/82
	CHKD. BY MCB	DATE 12/29/82

II Capacity and Flow

Fixtures

Water closet	10 fu	15 – 40 gpm
Lavatory	2 fu	3 gpm
Safety Shower	2 fu	5 gpm
Hose Bibs	2 fu	5 gpm
	16 fu	53 gpm

16 fu ⇒ 30 gpm < 40 gpm maximum demand from w.c.

Design piping for 50 gpm maximum flow.

III Water Requirements and Waste Volumes

A Water

$Q_{max} = 50$ gpm

Hazen - Williams $V = 1.318\ C R^{0.63} S^{0.54}$

$Q = 0.279\ C D^{2.63} S^{0.54}$

2 fps $\leq V \leq 10$ fps ; Use nomograph

If $V = 2$ and $C = 100$; $\phi = 4.5$ in

If $V = 10$ and $C = 100$; $\phi = 1.3$ in

Use $\phi = 3''$; $h_L = 13$ ft / 10^3 ft and $V = 2.2$

Use $\phi = 2.5''$; $h_L = 32$ ft / 10^3 ft and $V = 3.2$

Use $\phi = 2''$; $h_L = 100$ ft / 10^3 ft and $V = 5.1$

For plastic pipe, $C = 150$ and $S_1^{0.54} C_1 = S_2^{0.54} C_2$
at $Q = 50$ gpm

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA PN 37 NW Boundary	SHEET NO. 3 OF 4	
ITEM Domestic Water + Wastewater	BY LSJ	DATE 12/27/82
	CHKD. BY MCB	DATE 12/29/82

$$Q = 0.279\ C\ D^{2.63}\ S^{0.54}$$

To determine headloss for plastic pipe with $C = 150$, $Q_2 = Q_1$ and $D_2 = D_1$

$$C_2 S_2^{0.54} = C_1 S_1^{0.54}$$

$$S_2^{0.54} = \frac{C_1}{C_2} \cdot S_1^{0.54}$$

$$0.54 \log S_2 = 0.54 \log S_1 + \log\left(\frac{C_1}{C_2}\right)$$

$$\log S_2 = \log S_1 + \frac{1}{0.54} \log\left(\frac{C_1}{C_2}\right)$$

$$S_2 = \log^{-1}\left[\log S_1 + 1.85 \log\left(\frac{100}{150}\right)\right]$$

$$S_2 = \log^{-1}\left[\log S_1 - 0.326\right]$$

ϕ	S_1	S_2
3"	13 ft/10^3 ft	6.14 ft/10^3 ft
2.5"	32 ft/10^3 ft	13.9 ft/10^3 ft
2"	100 ft/10^3 ft	47.2 ft/10^3 ft

Distance from the new treatment building to the water line connection point is roughly 8,000 ft. The head loss in a 3" ϕ would be 49 ft; in a 2½" ϕ, 111 ft; and in a 2" ϕ, 378 ft.

Head regained from the altitude difference would be about 65 ft.±

A hydropneumatic tank will be used to allow sizing the water line down to 2" ϕ and avoid robbing the water system at Reservoir "F." The peak to average flow ratio makes use of a storage tank desirable.

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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA PN 37 NW Boundary		SHEET NO. 4	OF 4
ITEM Domestic Water + Wastewater		BY LLJ	DATE 12/27/82
		CHKD. BY	DATE 12/29/82

B. Wastewater Flows.

Permanent and resident	0		
Peak tenerant			
Government	2 @ 25 gpcd		50 gal
Contract	2 @ 25 gpcd		50 gal
Misc. flows		—	50 gal
			150 gal.

Peak daily flow rate $(150 \text{ gal})\left(\frac{24 \text{ hr}}{8 \text{ hr}}\right) = 450 \text{ gal}$

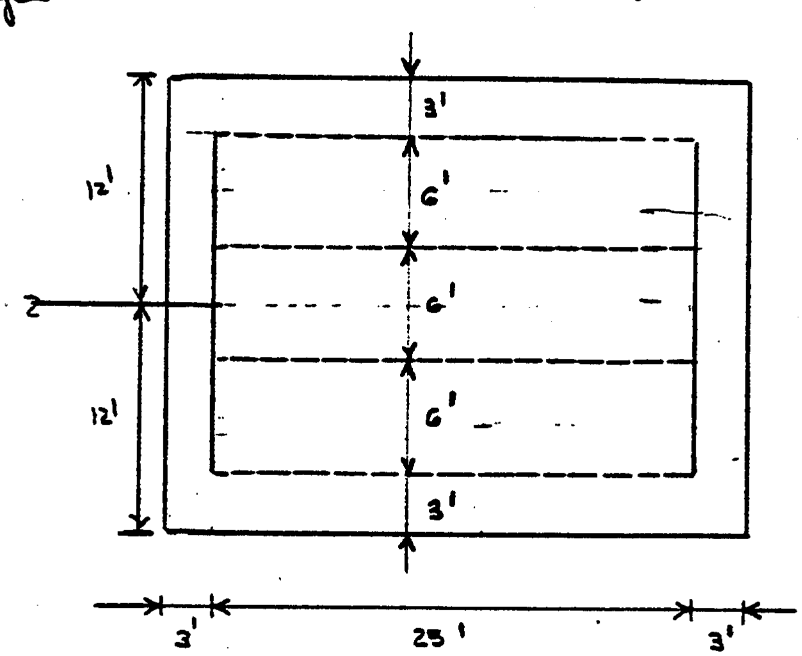
Minimum septic tank per TM 5-814-3 is 500 gal.

Application rate 0.75 gal/ft²/day

$$\frac{450 \text{ gal/day}}{0.75 \text{ gal/ft}^2\text{/day}}$$

600 ft² required

Use 24 ft width and 25 ft lengths of perforated pipe



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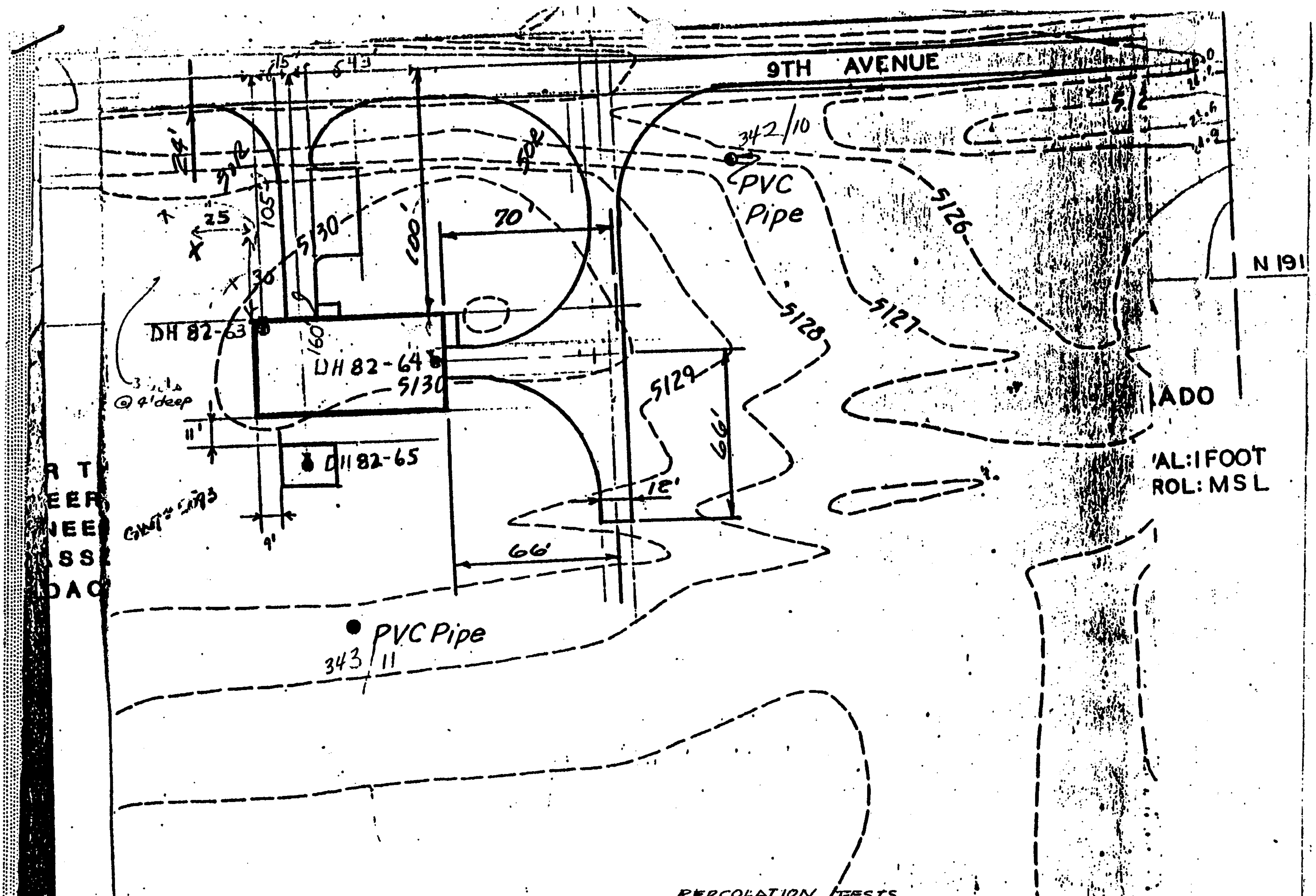


PLAN

SCALE: 1 INCH = 50 FEET

P1

TOP OF GRAVEL		4-4"	
SET H_2O	8:25	3'-5 1/2"	
	8:55	3'-7 1/8"	2 3/8
	9:23 (1)	3'-9 1/2"	1 5/8
RESET	9:25	3'-4"	
	9:55	6 7/8	2 7/8
	10:25 (2)	8	1 5/8
RESET	:30	4 3/8	
	11:00	6 1/4	1 7/8
	11:30 (3)	7 7/8	1 5/8
RESET	11 30	6 0	
	12:00	7 3/8	1 3/8
	12:30 (4)	8 7/8	1 1/2

P2

TOP OF GRAVEL		4'-4"	
SET H_2O	8:25	3'-7"	
	8 55	3 8 1/2	1 1/2"
	9:25 (1)	10 1/2	1 5/8
RESET	9:27	6 5/8	
	9:57	8 1/8	1 1/2
	10 27 (2)	9 3/8	1 1/4
RESET	10 30	7 1/8	
	11:00	8 1/8	1 3/8
	11 30 (3)	9 5/8	1 1/8
RESET	11 30	7 0	
	12 00	8 1/2	1 0
	12 30 (4)	9 1/8	1 1/8

P3

TOP OF GRAVEL		4'-4"	
SET H_2O	8:27	3'-5 1/2"	
	8 57	- 11 1/4	3 3/8
RAIN DELAY →	9:27 (1)	4'-1 1/8"	2 1/8
RESET	9:30	3'-4 3/4	
	10:00	7 1/4	2 1/2
	10 30 (2)	9	1 3/4
RESET	10 30	3'-6"	
	11:00	8 3/4	2 1/4
	11:30 (3)	9 1/2	1 1/4
RESET	11 30	4 1/2	
	12 00	6 3/8	1 7/8
	12 30 (4)	8 —	1 5/8

PERCOLATION TESTS
RMA
NW BOUNDARY TRTMT BLDG
7-2 1987

APPENDIX D

STRUCTURAL CALCULATIONS

OMAHA DISTRICT | COMPUTATION SHEET | CORPS OF ENGINEERS

PROJECT	SHEET NO. 1	OF
ITEM Recharge Well + Discharge Well Valve - Pit Vault Design	BY KMH	DATE 12/15/82
	CHKD. BY ECM	DATE 3/4/83

Assume the following....

inside vault dimensions ⇒ { plan ⇒ 8'-0" x 5'-6"; height ⇒ 7'-0" (6'-0" below + 1'-0" above finish grade) }

vault roof slab ⇒ ~6" (∴ $w_D \approx$ 75 psf)

vault walls ⇒ ~6" (∴ $w_D \approx$ 75 psf)

vault floor slab ⇒ ~8" (∴ $w_D \approx$ 100 psf)

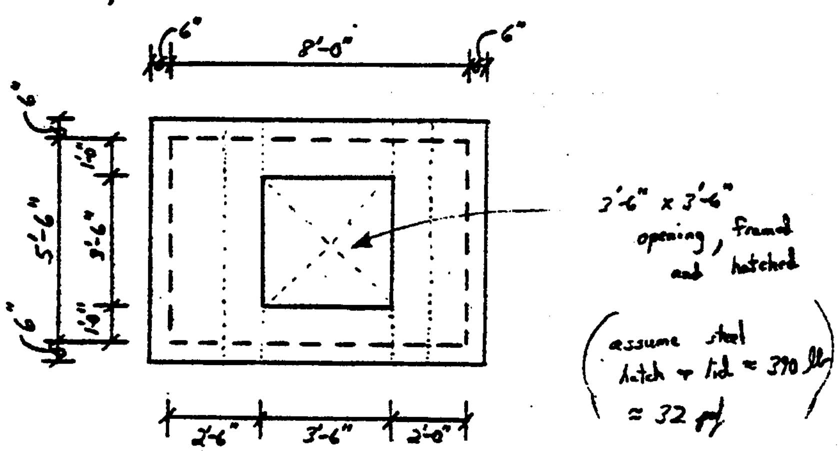
∴ Top of roof slab is ~ 1'-6" above finish grade (∴ no vehicular loads)

assume 35 psf ground snow load

assume f'_c = 4000 psi

assumed roof design live load ⇒ 100 psf

assume roof slab plan dimensions as follows ...



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OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT		SHEET NO. 2	OF
ITEM		BY KMH	DATE 12/15/82
		CHKD. BY ECM	DATE 3/4/83

assume slab spans one-way across short vault dimension

assuming $w_D = 75$ psf + $w_L = 100$ psf

$$w_u = (1.4)(75) + (1.7)(100) \approx 105 + 170 = 275 \text{ plf}$$

$$M_u = \frac{w_u l^2}{8} = \frac{(275)(6')^2}{(8)} = 1237.5 \text{ 'lb}$$

for $t = 6"$ assume $d \approx 3"$ $\therefore$ $F = .009$

$$\therefore \quad K_u \approx \frac{1.2375}{.009} \approx 137.5$$

$$\rho \approx .00263 < \rho_{min.} = .0033$$

$$A_s \text{ (req'd)} = (.0033)(12")(3") \approx .1188 \text{ in}^2/\text{ft}$$

$\therefore$ use #4 @ 18" $(A_s = .13 \text{ in}^2/\text{ft})$

for 1'-6" strips adjacent to 3'-6" x 3'-6" opening ...

assume $w_u = (1.4)\left[\left(1' + \frac{3.5'}{2}\right)(75 \text{ psf})\right] + (1.7)\left[\left(1' + \frac{3.5}{2}\right)(100 \text{ psf})\right] =$

$$w_u = (1.4)(206.25) + (1.7)(275) = 756.25 \text{ plf}$$

$$M_u = \frac{(756.25)(6')^2}{(8)} = 3403 \text{ 'lb}$$

$$K_u \approx \frac{3.403}{.009} = 378.1 \quad \Rightarrow \quad \rho = .00748$$

$$A_s \text{ (req'd)} = (.00748)(12")(3") = .2694 \text{ in}^2/\text{ft}$$

$\therefore$ place 1 - #4 additional bar each side of opening
$(A_s = .20 \text{ in}^2)$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT	SHEET NO. 3 OF	
ITEM	BY KMH	DATE 12/16/82
	CHKD. BY ECM	DATE 3/4/83

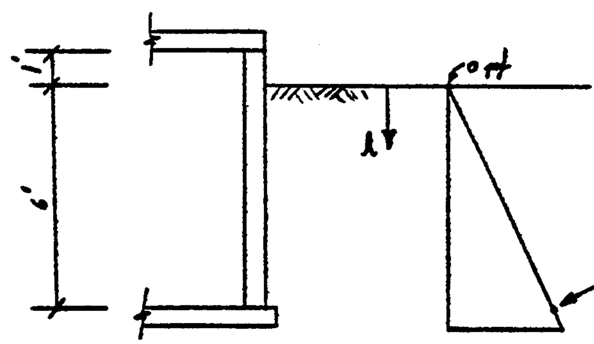
Design Vault Walls

assume .... walls span vertically from roof to base slabs

$\gamma_{soil} \approx 135$ pcf

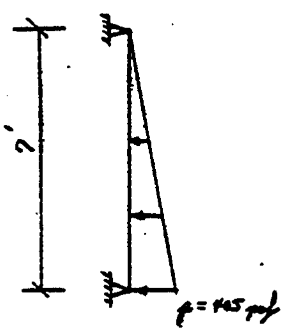
$K_o \approx .5$

∴ assume the following pressure distribution on the walls ....



$p_o = (\gamma_{soil})(h)(K_o) = (135)(6')(.5) = 405$ psf

making the following simple beam (conservative) loading assumptions ....



we have ... $M_{max.} = (.1283)(w)(l) = (.1283)\left[(405)(7')(\frac{1}{2})\right](7') = 1273$ 'lb

∴ $M_u = (1.7)(1273) = 2164$ 'lb

for $t = 6''$ assume $d = 3''$ $\therefore F = .009$

$\therefore K_u = \frac{2.164}{.009} = 240.5$

$\rho = .0047$

$A_s\ (\text{req'd}) = (.0047)(12'')(3'') = .1692\ \square''/ft$

By ACI 318-77, section 14.2 ...

$$\begin{cases} \text{min. horiz. steel} \rightarrow A_s = (.0020)(12'')(6'') = .144\ \square''/ft \\ \text{min. vert. steel} \Rightarrow A_s = (.0012)(12'')(6'') = .0864\ \square''/ft \end{cases}$$

Now, redesign wall steel using moment coefficients from PCA publication "Rectangular Concrete Tanks" ...

assume a triangular pressure distribution on the walls (for the full 7' height) resulting from a liquid pressure $[w = (135)(.5) = 67.5\ pcf]$

reference Table III assuming ... $\begin{cases} b = 8.0' \\ c = 5.5' \\ a = 7.0' \end{cases}$ $\begin{cases} \therefore \frac{b}{a} = \frac{8.0}{5.5} = 1.45 \\ \frac{c}{a} = \frac{5.5}{7.0} = .7857 \end{cases}$

use tables for $b/a = 1.5$ + $c/a = .75$

$$\therefore M_x\ (\text{max}) = \begin{pmatrix} +.032 \\ -.007 \end{pmatrix}(67.5)(7)^3 = \begin{Bmatrix} +740.9 \\ -162.1 \end{Bmatrix} ft \cdot lb$$ vert. all walls

$$M_y\ (\text{max.}) = \begin{pmatrix} +.022 \\ -.036 \end{pmatrix}(67.5)(7)^3 = \begin{Bmatrix} +509.4 \\ -833.5 \end{Bmatrix} ft \cdot lb$$ horiz. long wall

$$M_z\ (\text{max.}) = \begin{pmatrix} +.008 \\ -.004 \end{pmatrix}(67.5)(7)^3 = \begin{Bmatrix} +185.2 \\ -92.6 \end{Bmatrix} ft \cdot lb$$ horiz. short wall

$\oplus$ = tension on inside , $\ominus$ = tension on outside

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT		SHEET NO. 5	OF
ITEM		BY KMH	DATE 12/17/82
		CHKD. BY ECM	DATE 3/4/83

Vertical Steel Design

$M_u = (740.9)(1.7) = 1259.5\text{ 'lb}$

for $t = 6"$ assume $d = 2.5"$ ∴ $F = .00625$

$K_u = \frac{1.2595}{.00625} = 201.5$

$\rho = .00386$

$A_s(\text{req'd}) = (.00386)(12")(2.5") = .116^{\square"}/\text{ft}$
Minimum steel $.0864^{\square"}/\text{ft}$

Horizontal Steel Design

$M_u = (833.5)(1.7) = 1417.0\text{ 'lb}$

$K_u = \frac{1.417}{.00625} = 226.7$

$\rho = .00439$

$A_s(\text{req'd}) = (.00439)(12")(2.5") = .132^{\square"}/\text{ft}$
Minimum steel $.144^{\square"}/\text{ft}$

$$\therefore \text{ Use } \left\{ \begin{array}{llll} \#4 @ 14" \text{ o.c.} & \text{vert.} & (A_s = .17^{\square"}/\text{ft}) \\ \#4 @ 16" \text{ o.c.} & \text{horiz.} & (A_s = .145^{\square"}/\text{ft}) \end{array} \right\} \text{ All walls}$$

assume worst possible shear, conservatively, as $(405\text{ plf})(8')(\tfrac{1}{2}) = 1620\text{ lb}$

$V_u = (1.7)(1620) = 2754\text{ lb}$

$\phi V_c = (.85)(2)(\sqrt{4000})(12")(2.5") = 3225\text{ lb} > V_u$ ✓ ok

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OMAHA DISTRICT | COMPUTATION SHEET | CORPS OF ENGINEERS

PROJECT | SHEET NO. 6 OF

ITEM | BY KMH | DATE 12/17/82

CHKD. BY ECM | DATE 3/4/83

Base Slab Design

Roof Slab Dead Load $\approx (9')(6.5')(.5')(150\ pcf) \approx 4387.5$ lb

Roof Slab Live Load $\approx (9')(6.5')(100\ psf) = 5850$ lb

Wall Dead Load $= [(9' + 5.5')(2)](7')(.5')(150\ pcf) = 15,225$ lb

$$w_u \text{ (base slab)} \approx \left[\frac{(1.4)(4387.5 + 15,225) + (1.7)(5850)}{(7'\text{-}2'')(9'\text{-}8'')}\right] = \left[\frac{37,402.5 \text{ lb}}{69.277 \square'}\right] \approx$$

$\therefore\ w_u \approx 539.9$ psf $<< 1200$ psf (max. allow. brg.)

Reference Table III of PCA "Rectangular Concrete Tanks"

$\left.\begin{array}{l} b = 8.0' \\ a = 5.5' \end{array}\right\}$ $\frac{b}{a} = \frac{8.0}{5.5} \approx 1.\overline{45}$

use the table values for $\frac{b}{a} = 1.50$

$\therefore\ M_{ux}\ (max) = (.078)(539.9)(5.5)^2 \approx 1273.9$ 'lb (short direction)

$M_{uy}\ (max) \approx (.043)(539.9)(5.5)^2 = 702.3$ 'lb (long direction)

for short direction .... $t = 6''$, $d = 3''$, $F = .009$

$K_u = \frac{1.2739}{.009} \approx 141.5 \Rightarrow \therefore\ \rho = .0027 < \rho_{min} = .0033$

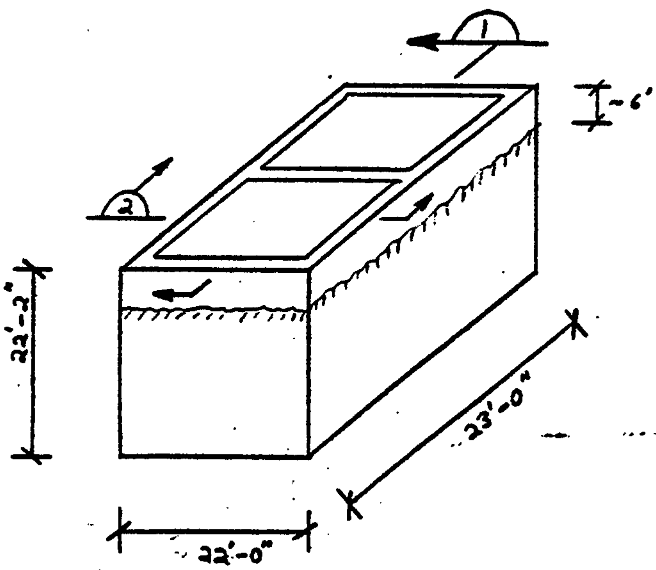
$A_s\ (req'd) = (.0033)(12'')(3'') \approx .119 \square''/ft$

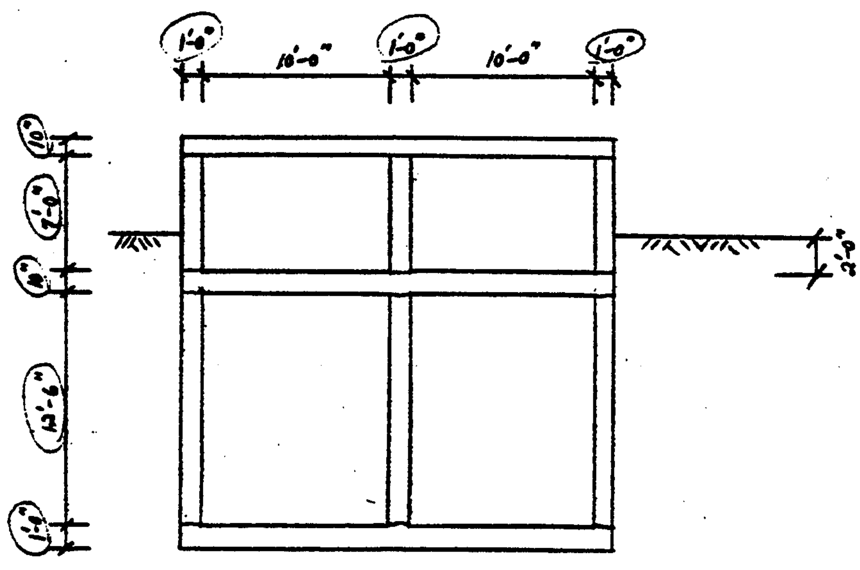
Min. Temp. + Shrinkage $\Rightarrow A_s = (.0018)(12'')(6'') = .1296 \square''/ft$

$\therefore$ use #4 @ 18" e.w. $(A_s = .13 \square''/ft)$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT		SHEET NO. 7	OF
ITEM Sump Vault Design		BY KMH	DATE 12/17/82
		CHKD. BY ECM	DATE 3/4/83

Assume the following general geometry....





Section 1

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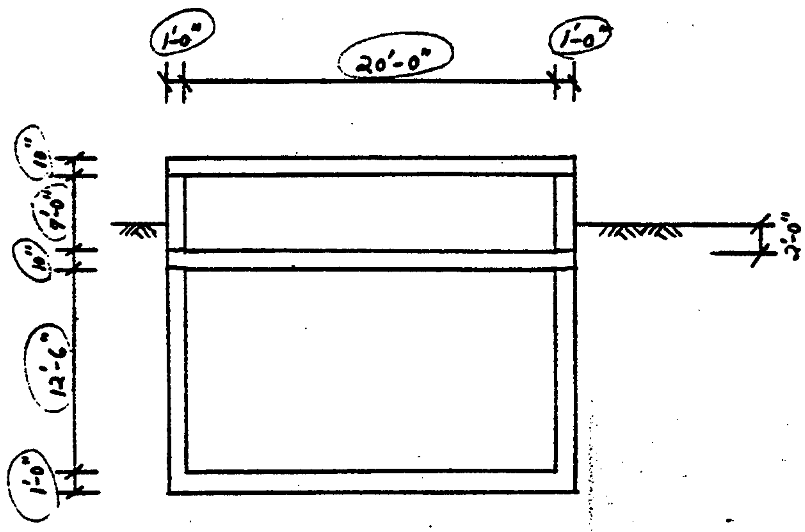
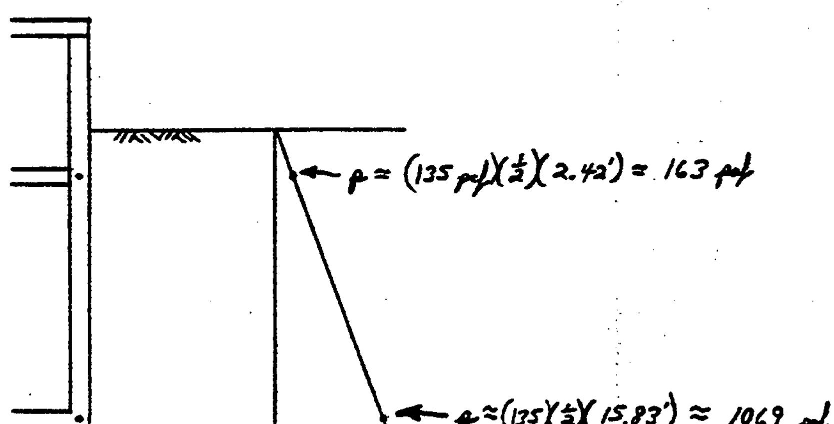
PROJECT	SHEET NO. 8	OF
ITEM	BY KMH	DATE 12/20/82
	CHKD. BY ECM	DATE 3/4/83



Section 2

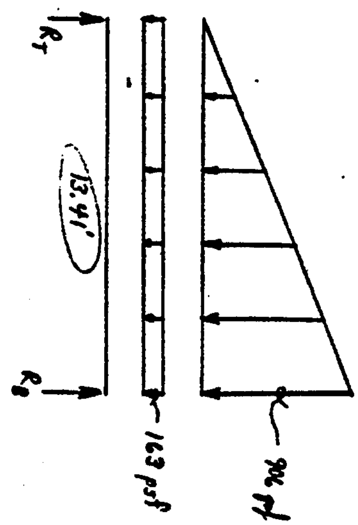
Conservatively assume all walls to span (one-way) vertically from base slab to intermediate slab. Assume the following loading diagram...



OMAHA DISTRICT — **COMPUTATION SHEET** — CORPS OF ENGINEERS

PROJECT	SHEET NO. 9	OF
ITEM	BY KMH	DATE 12/20/82
	CHKD. BY ECM	DATE 3/4/83

Design Vertical Wall Reinf.



$$M_{max}\ (\text{triang. load})\ @\ (.5774)(l) = (.1283)(W)(l) \approx (.1283)\left[(906)(13.41')(\tfrac{1}{2})\right](13.41') \approx$$

$$\approx 10{,}452\ \text{'lb}$$

$$M\ (\text{unif. load})\ @\ (.5774)(l) \approx \left(\frac{wx}{2}\right)(l-x) \approx \frac{(163)\left[.5774(13.41')\right]}{(2)}\left[(1-.5774)(13.41')\right] \approx$$

$$\approx 3576\ \text{'lb}$$

$$\Sigma M\ @\ (.5774)(l) \approx 14{,}028\ \text{'lb}$$

$$M_{max.}\ (\text{unif. load})\ @\ .5l = \frac{wl^2}{8} = \frac{(163)(13.41')^2}{(8)} = 3664\ \text{'lb}$$

$$M\ (\text{triang. load})\ @\ \tfrac{1}{2}l = \left(\frac{Wx}{3l^2}\right)(l^2-x^2) = \frac{\left[(906)(13.41')(\frac{1}{2})\right](6.705')}{(3)(13.41')^2}\left[(13.41)^2-(6.705)^2\right] =$$

$$\approx 10{,}183\ \text{'lb}$$

$$\Sigma M\ @\ \text{midspan} \approx 13{,}847\ \text{'lb}$$

$$R_T = \frac{wl}{2} + \frac{W}{3} = \frac{(163)(13.41)}{(2)} + \frac{(906)(13.41)(\frac{1}{2})}{(3)} \approx 3118\ \text{lb}$$

$$R_B = \frac{wl}{2} + \frac{2W}{3} = 5143\ \text{lb}$$

∴ consider $M_{max} = 14{,}028$ 'lb

$M_u = (1.7)(14{,}028) = 23{,}848$ 'lb

Note that maximum moment in a simple span beam loaded as shown would be slightly higher between .5ℓ and .5774 ℓ. However, the wall will actually be somewhat of a 2-span continuous beam vertically, which will tend to reduce positive moments and produce negative moments at the intermediate slab level. Also, there will be some 2-way action in the walls, which will tend to reduce all vertical span moments, etc.

for $t = 12"$ $d = 9.5"$ $F = .09025$

$K_u = \frac{23{,}848}{.09025} = 264.2$

$\rho = .0051$

A_s (req'd) $= (.0051)(12")(9.5") = .583$ □"/ft

∴ use #7 @ 12" ($A_s = .60$ □"/ft)
or #6 @ 9" ($A_s = .59$ □"/ft)
} vertically, interior face of all exterior walls

assuming 1 tank completely filled and the other completely dry, a similar loading condition would occur on the interior wall with
$\gamma_{H_2O} = 62.4$ pcf vs. $\gamma_{soil} = (135)(\frac{1}{2}) = 67.5$ pcf

∴ use same reinf. as above for both faces of common tank wall

by ACI 318-77, section 14.2 ....

min. horiz. steel ⇒ $A_s = (.0020)(12")(12") = .288$ □"/ft

min. vert. steel ⇒ $A_s = (.0012)(12")(12") = .173$ □"/ft

$V_u = (1.7)(R_B) = (1.7)(5143) = 8743$ lb

$\phi V_c = (.85)(2)(\sqrt{4000})(12")(9.5") = 12{,}257$ lb $> V_u$ ok in shear

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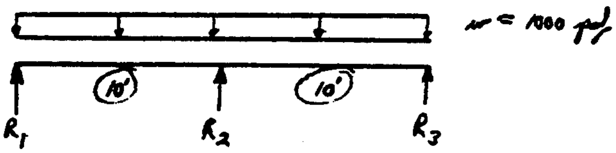
assume the short exterior walls to span horizontally (2-span continuous)

the worst case possible would be ....



$R_1 = R_3 = \frac{3}{8} wl = (\frac{3}{8})(1000)(10') = 3750$ lb

$R_2 = \frac{5}{4} wl = (\frac{5}{4})(1000)(10) = 12{,}500$ lb

$$\left\{ \begin{array}{l} M_{max} = \frac{9}{128} wl^2 = (\frac{9}{128})(1000)(10)^2 = 7031 \text{ 'lb} \\ M_u = (1.7)(7031) = 11{,}953 \text{ 'lb} \end{array} \right\}$$ positive moments

$$\left\{ \begin{array}{l} M_{max} = \frac{wl^2}{8} = \frac{(1000)(10)^2}{(8)} = 12{,}500 \text{ 'lb} \\ M_u = (1.7)(12{,}500) = 21{,}250 \text{ 'lb} \end{array} \right\}$$ negative moment

Positive Reinf. $\Rightarrow$
$$\left\{ \begin{array}{l} K_u = \frac{11{,}953}{.09025} = 132.4 \\ \rho \approx .00253 < \rho_{min} = .0033 \\ A_s (\text{req'd}) = (.0033)(12")(9.5") = .376 \ \square"/ft \end{array} \right.$$

Negative Reinf. $\Rightarrow$
$$\left\{ \begin{array}{l} K_u = \frac{21.25}{.09025} \approx 235.5 \\ \rho \approx .00457 \\ A_s (\text{req'd}) = (.00457)(12")(9.5") = .52 \ \square"/ft \end{array} \right.$$

$$\left\{ \begin{array}{l} V_u (max) = (\frac{12{,}500}{2})(1.7) = (6250)(1.7) = 10{,}625 \text{ lb} \\ \phi V_c = 12{,}257 \text{ lb} > V_u \quad \text{ok} \end{array} \right\}$$

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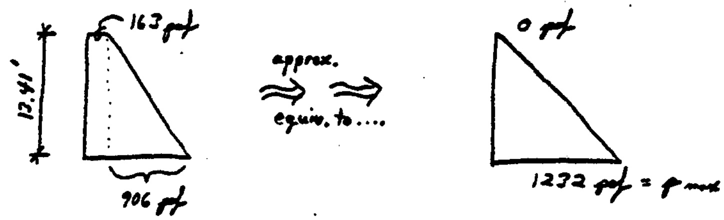
Check Design as a Box using PCA publication "Rectangular Concrete Tanks"

Pressure Diagram for lower compartment exterior walls $\Rightarrow$



$$A = (163)(13.41) + \frac{(906)(13.41)}{(2)} = 8260.56 \qquad A' = \frac{(p_{max})(13.41)}{(2)}$$

$$A = A' \Rightarrow \therefore \quad p_{max} = \frac{(8260.56)(2)}{(13.41)} = 1232 \text{ psf}$$

from Table I .....

$a = 13.41$

$\therefore \quad w = 1232/13.41 = 91.87$

$\therefore \quad M_{max} = (coef)(w)(a^3) = (coef)(91.87)(13.41)^3 = (221,548)(coef.)$

$$M_{max}(x) = \begin{cases} (-.011)(221,548) = -2437\text{ 'lb} \\ (+.036)(221,548) = +7976\text{ 'lb} \end{cases}$$

$$M_{max}(y) = \begin{cases} (-.057)(221,548) = -12,628\text{ 'lb} \\ (+.021)(221,548) = +4653\text{ 'lb} \end{cases}$$

from Table III .....

$b = 20'$ $\quad c = 10'$ $\quad a = 12.5'$ $\quad \frac{b}{a} = \frac{20}{12.5} = 1.6$ $\quad \frac{c}{a} = \frac{10}{12.5} = .80$

$$M_x(max.) = \begin{cases} (+.032)(221,548) = +7090\text{ 'lb} \\ (-.007)(221,548) = -1551\text{ 'lb} \end{cases}$$

$$M_y(max) = \begin{cases} (+.022)(221,548) = +4874\text{ 'lb} \\ (-.036)(221,548) = -7976\text{ 'lb} \end{cases}$$

$$M_z(max) = \begin{cases} (+.008)(221,548) = +1772\text{ 'lb} \\ (-.004)(221,548) = -886\text{ 'lb} \end{cases}$$

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Select Vault Wall Steel Reinf.

Lower Compartment Walls

#6 @ 9" (A_s = .59 $\square$"/ft) vert., interior face of exterior walls

#6 @ 9" (A_s = .59 $\square$"/ft) vert., both faces of common int. wall

#4 @ 12" (A_s = .20 $\square$"/ft) vert., exterior face of exterior walls

#6 @ 10" (A_s = .53 $\square$"/ft) horiz., exterior face of exterior walls

#6 @ 9" (A_s = .59 $\square$"/ft) horiz., both faces of common int. wall

#6 @ 9" (A_s = .59 $\square$"/ft) horiz., interior face of exterior walls

Upper Compartment Walls

#4 @ 12" (A_s = .20 $\square$"/ft) each way, each face, typ.

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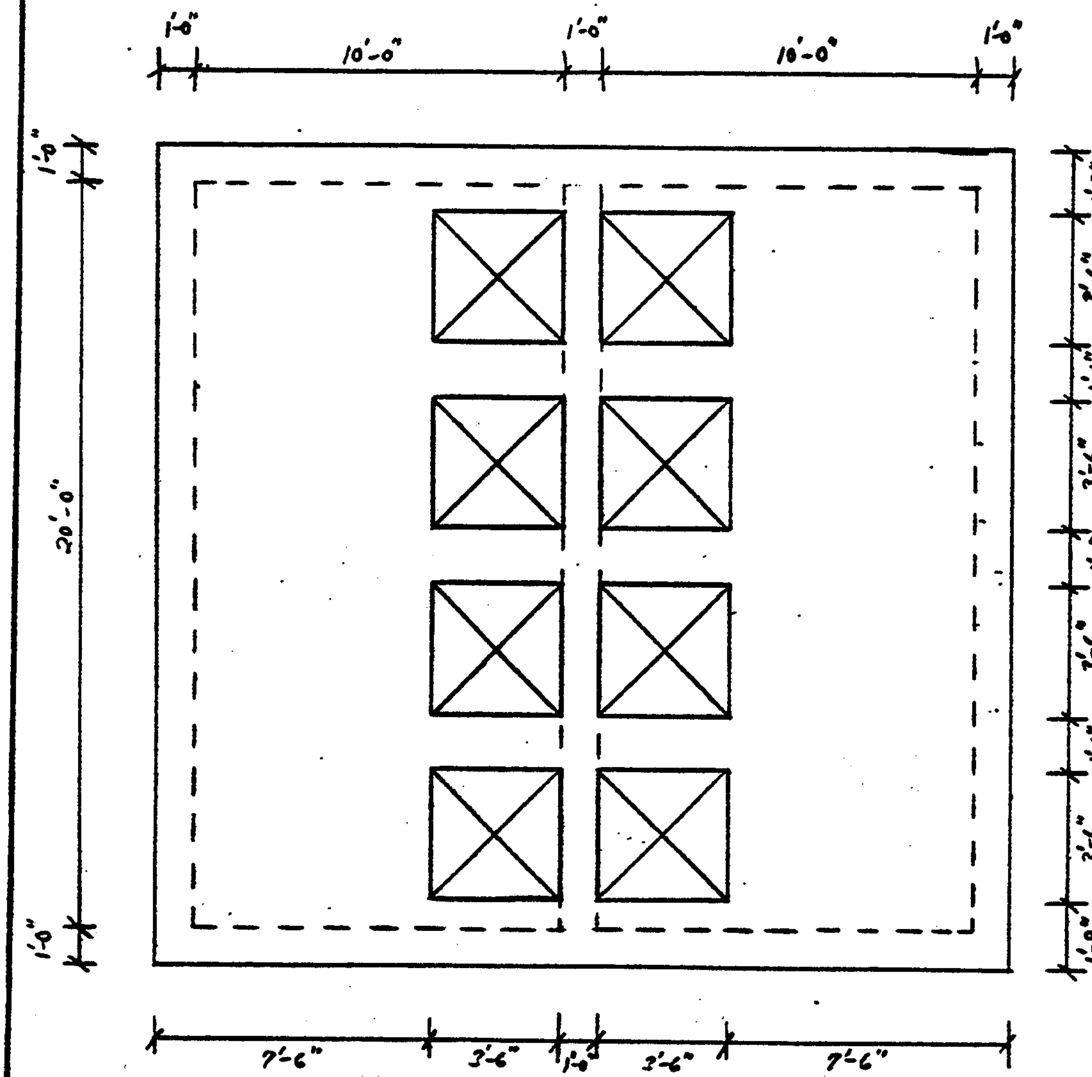
Roof Slab Design

Assuming the following general plan geometry ....



Assume a 2-span continuous beam action in slab supported at end walls and intermediate wall.

Assume { a 100 psf uniform design live load
+
a 1600 lb concentrated design live load (@ any location)

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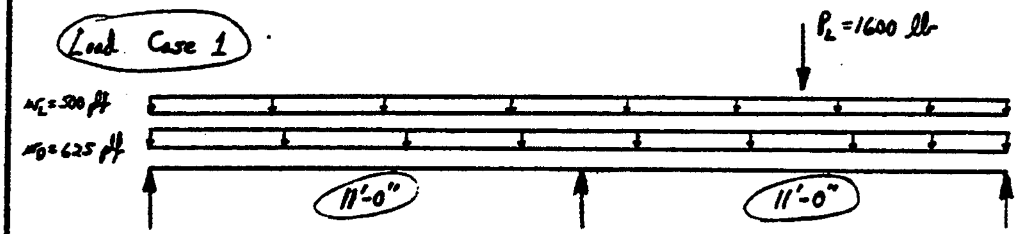
Design the 1'-6" wide beam strips between roof openings assuming ....

$$w_D = \left(\tfrac{10}{12}\right)(5')(150\ \text{pcf}) = 625\ \text{plf}$$

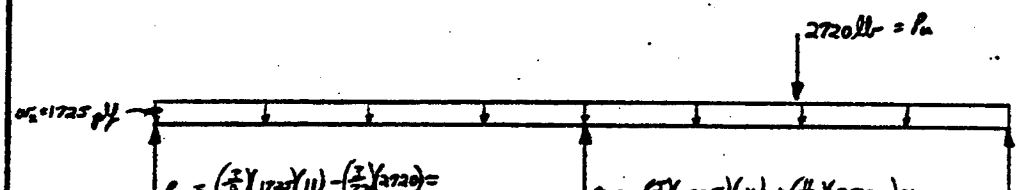
$$w_L = (100\ \text{psf})(5') = 500\ \text{plf}$$

Load Case 1



$$w_u = (1.4)(w_D) + (w_L)(1.7) = (1.4)(625) + (1.7)(500) = 1725\ \text{plf}$$

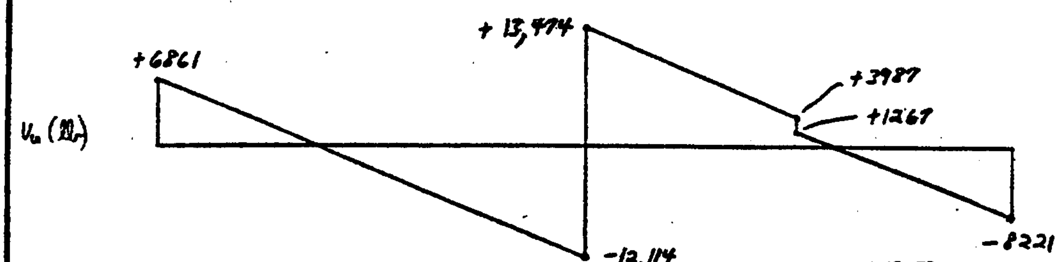
$$P_u = (1.7)(P_L) = (1.7)(1600) = 2720\ \text{lb}$$

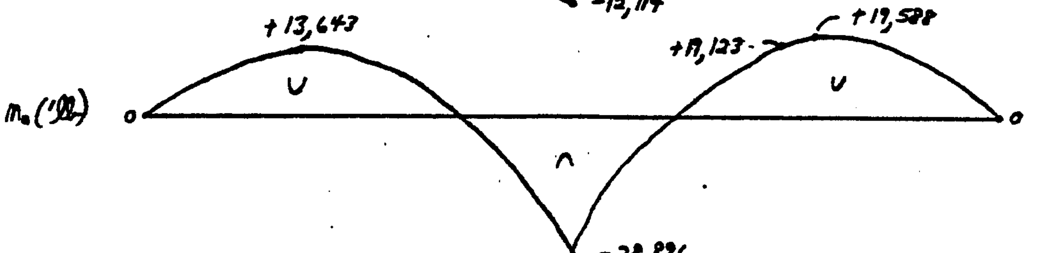


$R_1 = \left(\tfrac{3}{8}\right)(1725)(11) - \left(\tfrac{3}{32}\right)(2720) = 6861$ lb

$R_2 = \left(\tfrac{5}{4}\right)(1725)(11) + \left(\tfrac{11}{16}\right)(2720) = 25,589$ lb

$R_3 = \left(\tfrac{3}{8}\right)(11)(1725) + \left(\tfrac{13}{32}\right)(2720) = 8221$ lb





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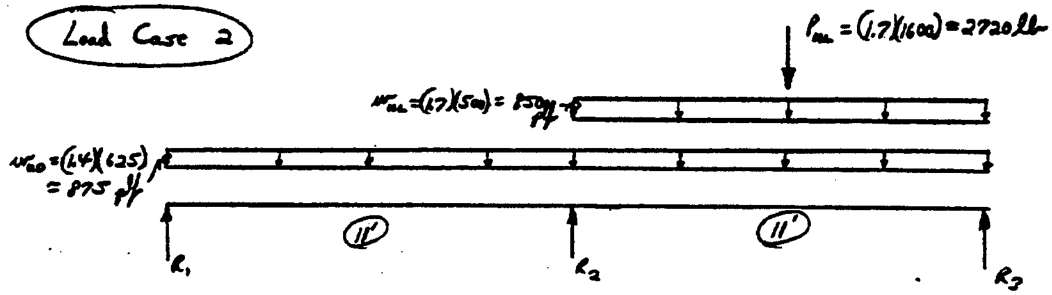
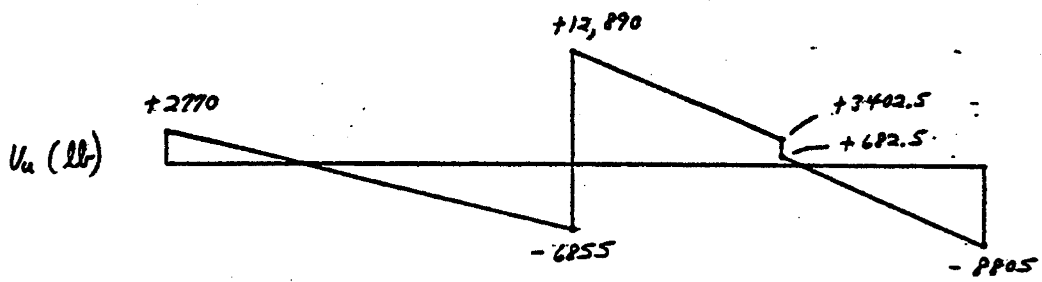
Load Case 2

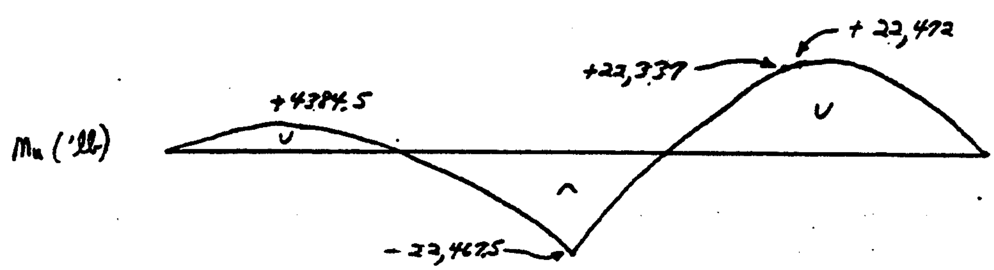


$$R_1 = \left(\tfrac{3}{8}\right)(875)(11') - \left(\tfrac{1}{16}\right)(850)(11') - \left(\tfrac{3}{32}\right)(2720) = 2770 \text{ lb}$$

$$R_2 = \left(\tfrac{5}{4}\right)(875)(11') + \left(\tfrac{5}{8}\right)(850)(11') + \left(\tfrac{11}{16}\right)(2720) = 19{,}745 \text{ lb}$$

$$R_3 = \left(\tfrac{3}{8}\right)(875)(11') + \left(\tfrac{7}{16}\right)(850)(11') + \left(\tfrac{13}{32}\right)(2720) = 8805 \text{ lb}$$





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Load Case 3

Max. shear would occur with full dead + live uniform loads on entire slab area and with concentrated live load adjacent to middle wall support.

$$\therefore \quad V_u(max) = \left(\tfrac{5}{8}\right)(1725)(11') + (2720) = 14{,}579 \text{ lb}$$

$$\therefore \begin{cases} M_u \text{ (max. positive)} = 22{,}472 \text{ 'lb} \\ M_u \text{ (max. negative)} = 28{,}896 \text{ 'lb} \\ V_u \text{ (max.)} = 14{,}579 \text{ lb} \end{cases}$$

for $\begin{cases} t = 10'' \\ b = 18'' \end{cases}$ $\quad d \approx 8''$ $\quad F = \dfrac{(18)(8)^2}{(12{,}000)} = .096$

$K_u = \dfrac{22.472}{.096} = 234.1$

$\rho \approx .00454$

$A_s(req'd) = (.00454)(18)(8) = .653^{\square''}$

$\therefore$ use 2 - #6 bars ($A_s = .88^{\square''}$) @ bottom of slab strip beam

$K_u = \dfrac{28.896}{.096} = 301$

$\rho \approx .00587$

$A_s(req'd) = (.00587)(18)(8) = .846^{\square''}$

$\therefore$ use 2 - #6 bars ($A_s = .88^{\square''}$) @ top of slab strip beam

$\phi V_c = (.85)(2)(\sqrt{4000})(18'')(8'') = 15{,}482 \text{ lb} > V_u \text{ (max.)}$

but $\dfrac{\phi V_c}{2} = 7741 \text{ lb} < V_u \text{ (max.)}$

$\therefore$ assume #3 stirrups

$$\begin{cases} S_{max} = \dfrac{d}{2} = \dfrac{8''}{2} = 4'' \leftarrow \text{governs} \\ S_{max} = 24'' \\ S_{max} = \dfrac{(.22^{\square''})(60{,}000)}{(50)(18'')} = 14.67'' \\ S_{max} = \dfrac{(.85)(.22^{\square''})(60{,}000)(8'')}{(14{,}579 - 15{,}482)} = N.A. \end{cases}$$

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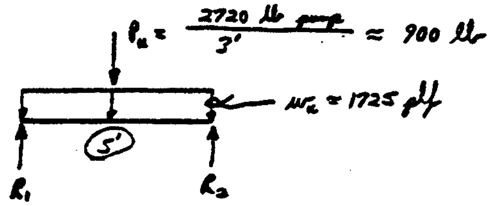
∴ use #3 stirrups @ 4" in slab strip beam between openings

minimum temp. + shrinkage reinf. in slab by ACI 318-77 section 7.12

$A_s(\text{min.}) = (.0018)(12")(10") = .216\ \square"/ft$

Design slabs to span between beam strips



$V_u(\text{max}) = R_1 = R_2 = [(1725)(5) + (900)](\frac{1}{2}) \approx 4762$ lb

$\phi V_c = (.85)(2)(\sqrt{4000})(12")(8") = 10,322$ lb $\gg V_u(\text{max})$ ok

$M_u(\text{max}) = \frac{(1725)(5)^2}{(8)} + \frac{(900)(5)}{(4)} = 6516$ 'lb

for $t = 10"$ $d \approx 8"$ $F \approx .064$

$K_u = \frac{6.516}{.064} = 101.8$

$\rho \approx (.00192)(\frac{4}{3}) = .002555 < \rho_{min.} = .0033$

$A_s(\text{req'd}) = (.002555)(12")(8") = .245\ \square"/ft$

∴ use #4 @ 10" ($A_s = .24\ \square"/ft$) e.w., T+B, typ. slab reinf.

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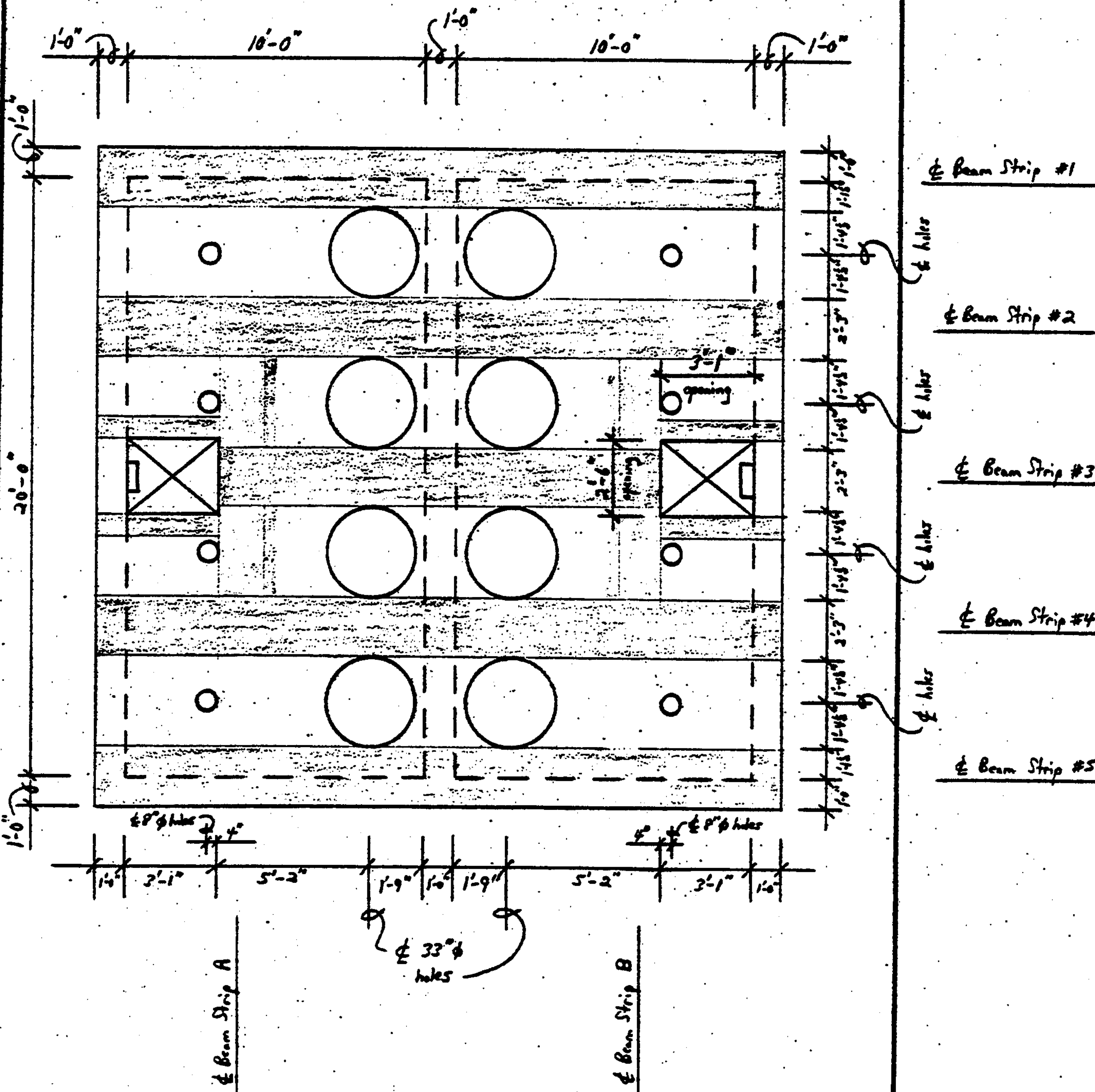
Intermediate Slab Design

Assuming the following general plan geometry ....



(Note: Beam strips are identified by shaded areas.)

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Assume a 2-span continuous beam action in slab strips #1 thru #5

Assume { a 100 psf uniform design live load
+
a 1600 lb concentrated design live load @ each 33"ϕ hole

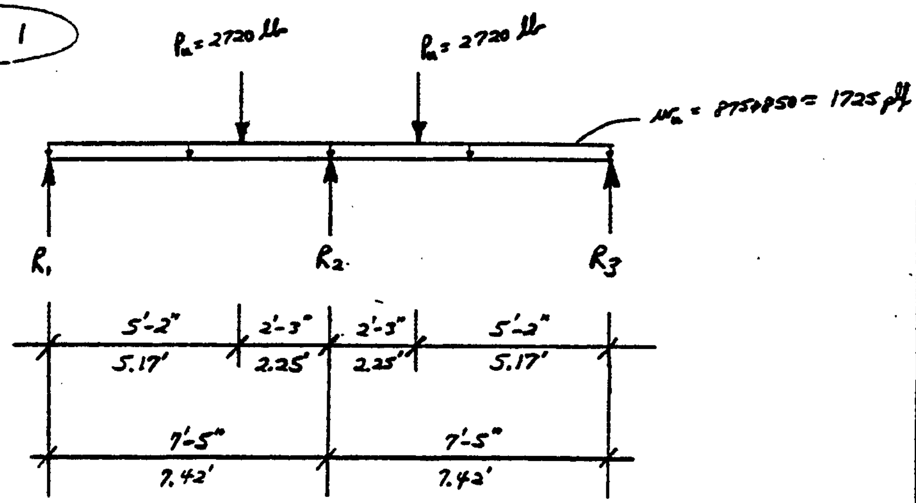
Design Beam Strip #3

$$\begin{cases} w_D = \left[\left(\frac{10"}{12}\right)(5')(150\ pcf)\right] = 625\ plf \\ w_L = (100\ psf)(5') = 500\ plf \\ P_L = \left[(1600\ lb)\left(\frac{1}{2}\right)\right](2) = 1600\ lb \end{cases}$$

∴ Factored Loads are ...

$$\begin{cases} w_{uD} = (1.4)(625) = 875\ plf \\ w_{uL} = (1.7)(500) = 850\ plf \\ P_{uL} = (1.7)(1600\ lb) = 2720\ lb \end{cases}$$

Load Case 1



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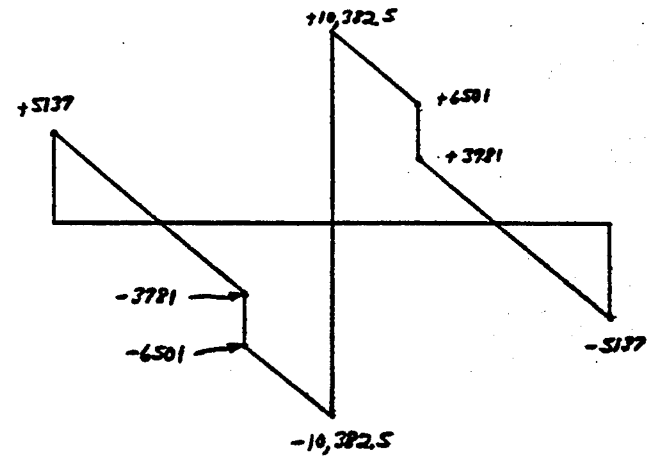
$$R_1 = R_3 = \left(\tfrac{3}{8}\right)(1725)(7.42) + \frac{(2720)(2.25)}{(4)(7.42)^3}\left[(4)(7.42)^2 - (5.17)(7.42 + 5.17)\right]$$

$$- \frac{(2720)(5.17)(2.25)}{(4)(7.42)^3}\left[(7.42) + (5.17)\right] \approx 4800 + 581 - 244 \approx 5137 \text{ lb}$$

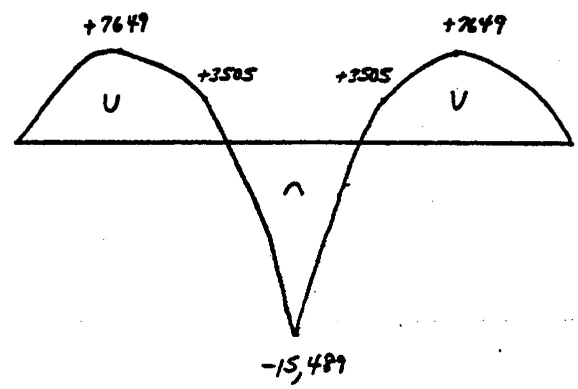
$$R_2 \approx \left(\tfrac{5}{4}\right)(1725)(7.42) + \left\{\frac{(2720)(5.17)}{(2)(7.42)^3}\left[(2)(7.42)^2 + (2.25)(7.42 + 5.17)\right]\right\}\left\{2\right\} =$$

$$\approx 15{,}999 + 4766 = 20{,}765 \text{ lb}$$

V_u (lb)



M_u ('lb)



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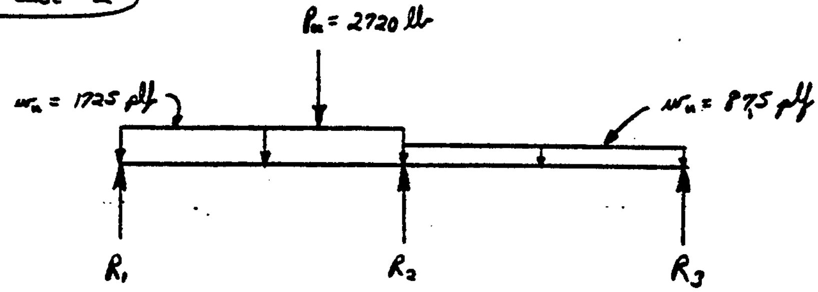
Load Case 2



$$R_1 = \left(\tfrac{2}{16}\right)(1725)(7.42) - \left(\tfrac{1}{16}\right)(875)(7.42) + \frac{(2720)(2.25)}{(4)(7.42)^3}\left[(4)(7.42)^2 - (5.17)(7.42 + 5.17)\right] =$$

$$= 5600 - 406 + 581 \approx 5775 \text{ lb}$$

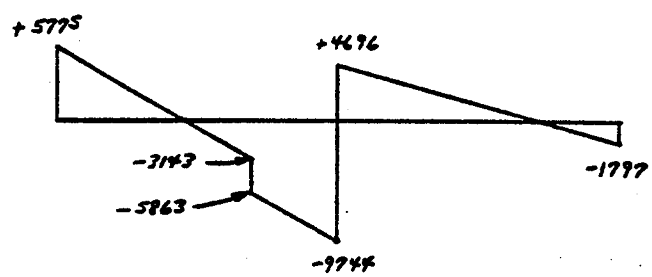
$$R_2 = \left(\tfrac{5}{8}\right)(1725)(7.42) + \left(\tfrac{5}{8}\right)(875)(7.42) + \frac{(2720)(5.17)}{(2)(7.42)^3}\left[(2)(7.42)^2 + (2.25)(7.42+5.17)\right] \approx$$

$$= 8000 + 4058 + 2383 \approx 14{,}440 \text{ lb}$$

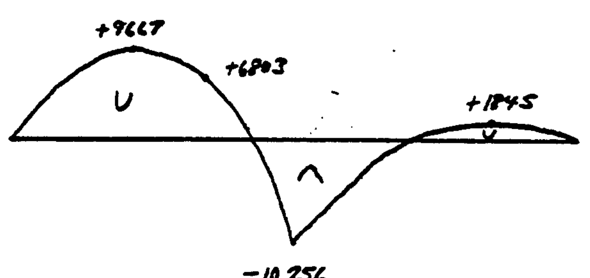
$$R_3 = \left(\tfrac{2}{16}\right)(875)(7.42) - \left(\tfrac{1}{16}\right)(1725)(7.42) - \frac{(2720)(5.17)(2.25)}{(4)(7.42)^3}\left[7.42 + 5.17\right] \approx$$

$$= 2840 - 800 - 244 \approx 1797 \text{ lb}$$

V_u (lb)



M_u ('lb)



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$\therefore \begin{cases} M_u \text{ (max. positive)} \approx 9667\ '\text{lb} \\ M_u \text{ (max. negative)} = 15{,}489\ '\text{lb} \\ V_u \text{ (max.)} = 10{,}382.5 \text{ lb} \end{cases}$

for $\begin{cases} t = 10'' \\ b = 27'' \end{cases}$ $\quad d = 8'' \quad F = \frac{bd^2}{12{,}000} = \frac{(27)(8)^2}{12{,}000} = .144$

$K_u = \frac{9.667}{.144} \approx 67.1$

$\rho \approx (.0013)(\frac{4}{3}) \approx .0017 < \rho_{min} = .0033$

$A_s \text{ (req'd)} = (.0017)(27'')(8'') \approx .374^{\square''}$

$K_u = \frac{15.489}{.144} = 107.6$

$\rho = (.00203)(\frac{4}{3}) = .0027 < \rho_{min} = .0033$

$A_s \text{(req'd)} = (.0027)(27'')(8'') = .585^{\square''}$

$\therefore$ use $\begin{cases} 4 - \#4 \text{ bars in top of Beam Strip \#3} & (A_s = .80^{\square''}) \\ 4 - \#4 \text{ bars in bottom of " " "} & (A_s = .80^{\square''}) \end{cases}$

$\phi V_c = (.85)(2)(\sqrt{4000})(27'')(8'') = 23{,}224 \text{ lb}$

$\frac{\phi V_c}{2} \approx 11{,}612 \text{ lb} > V_u \text{(max)} = 10{,}383 \text{ lb}$ ✓ ok in shear

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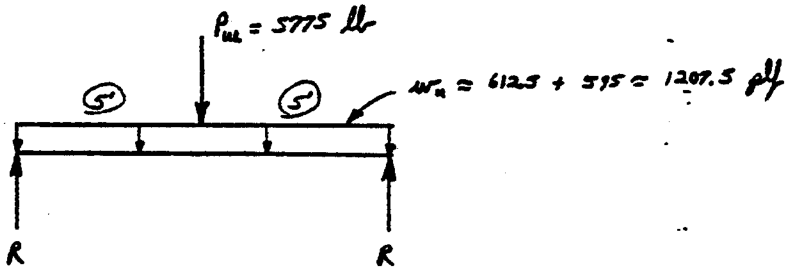
Design Beam Strips A + B

$$\begin{cases} w_D \approx \left[\left(\tfrac{1}{2}\right)\left(3'\text{-}9\tfrac{1}{2}'' + 3'\text{-}1''\right)\right]\left(\tfrac{10''}{12}\right)(150\ pcf) = (3.5')\left(\tfrac{10}{12}\right)(150) = 437.5\ plf \\ w_L \approx (100\ psf)(3.5') = 350\ plf \\ P_{RL} = 5775\ lb\ (\text{see max. } R_1 \text{ for Beam Strip \#3; see sht. \#20}) \end{cases}$$

$$\therefore \begin{cases} w_{uD} = (1.4)(437.5) = 612.5\ plf \\ w_L = (1.7)(350) = 595\ plf \end{cases}$$



$$R = \left[(1207.5)(10') + (5775)\right]\left(\tfrac{1}{2}\right) = 8925\ lb = V_u\ (max.)$$

$$M_u(max.) = \frac{wl^2}{8} + \frac{Pl}{4} = \frac{(1207.5)(10)^2}{(8)} + \frac{(5775)(10')}{(4)} = 29{,}531\ 'lb$$

for $\begin{cases} t = 10'' \\ b = 24'' \end{cases}$ $\quad d = 7'' \quad F = \dfrac{(24)(7)^2}{(12{,}000)} = .098$

$$K_u = \frac{29.531}{.098} \approx 301.3$$

$$\rho \approx .00588$$

$$A_s(req'd) = (.00588)(24'')(7'') = .988^{\square''}$$

$\therefore$ use $\begin{cases} 4 - \#6 \text{ bars in bottom of Beam Strips A + B } (A_s = 1.76^{\square''}) \\ 4 - \#6 \text{ bars in top '' '' '' '' } (A_s = 1.76^{\square''}) \end{cases}$

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$\phi V_c = (.85)(2)(\sqrt{4000})(24")(7") \approx 18{,}063$ lb

$\frac{\phi V_c}{2} = 9031$ lb $> V_u (max.) = 8925$ lb ✓ ok in shear

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Design Beam Strips #2 + #5

$w_D = \left(\frac{10''}{12}\right)(5')(150\ pcf) = 625\ plf$

$w_L \approx (100\ psf)(5') = 500\ plf$

$P_L = \left[(1600\ lb)(\tfrac{1}{2})\right](2) = 1600\ lb$

$\therefore$ Factored Loads are ....

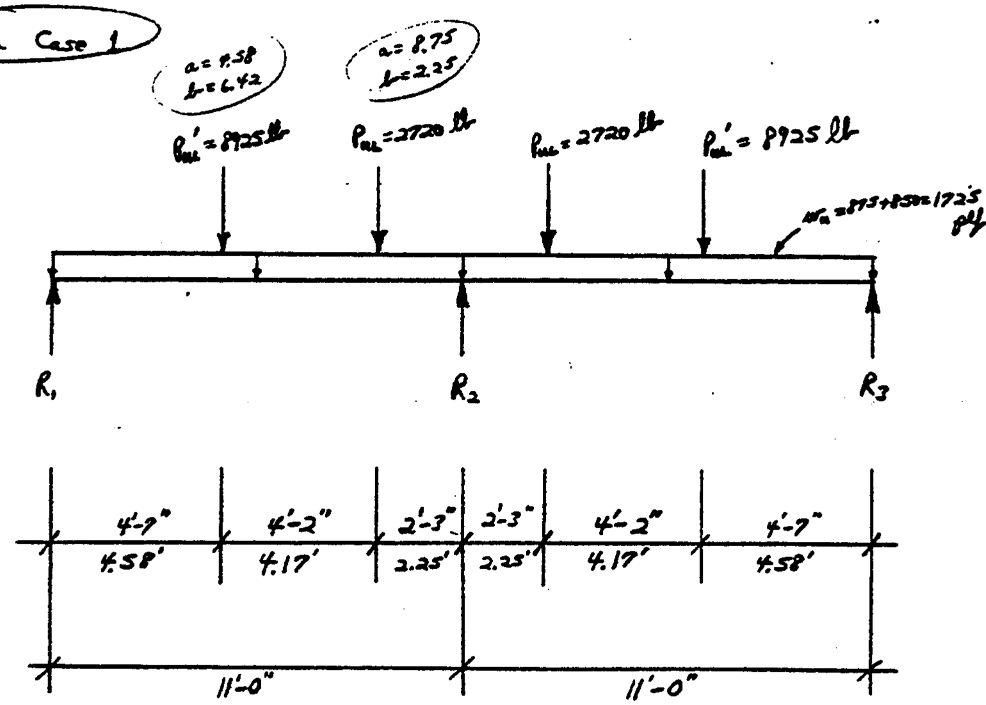
$w_{uD} = (1.4)(625) = 875\ plf$

$w_{uL} = (1.7)(500) = 850\ plf$

$P_{uL} = (1.7)(1600) = 2720\ lb$

$P_{uL}' = 8925\ lb$ (see max. R for Beam Strips A+B; see sht #22)

Load Case 1



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$$R_1 = R_3 = \left(\tfrac{3}{8}\right)(1725)(11') + \frac{(8925)(6.42)}{(4)(11)^3}\left[(4)(11)^2 - (4.58)(11 + 4.58)\right]$$

$$+ \frac{(2720)(2.25)}{(4)(11)^3}\left[(4)(11)^2 - (8.75)(11 + 8.75)\right]$$

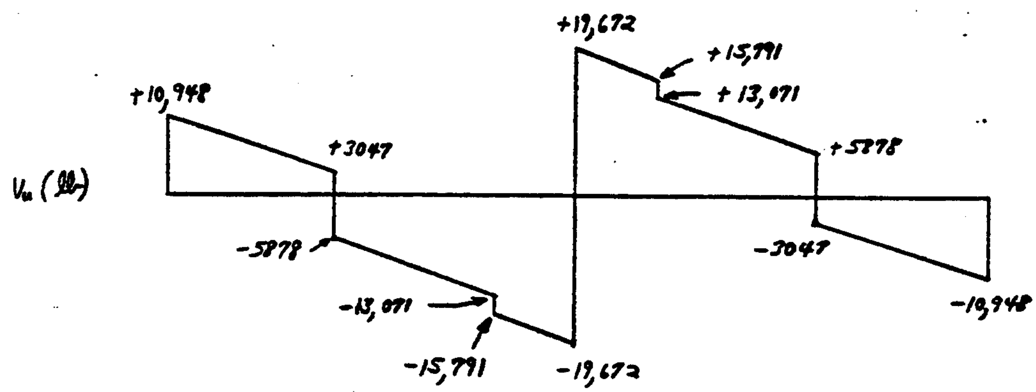
$$- \frac{(8925)(4.58)(6.42)}{(4)(11)^3}\left[11 + 4.58\right] - \frac{(2720)(8.75)(2.25)}{(4)(11)^3}\left[11 + 8.75\right] \approx$$

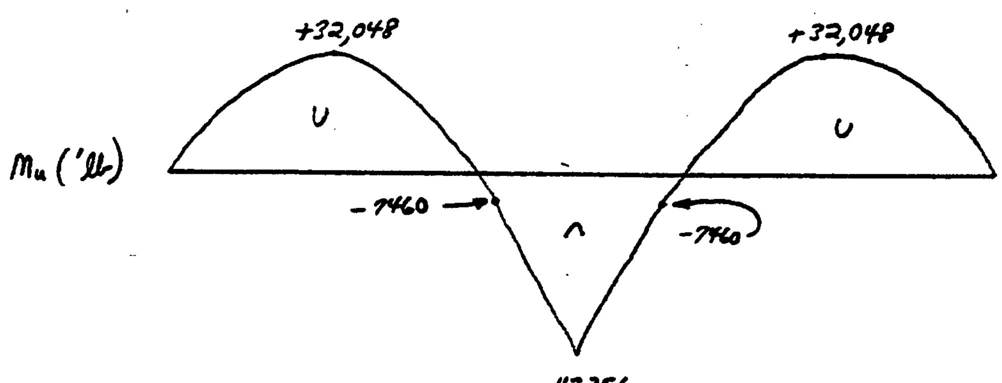
$$\approx 7116 + 4441 + 358 - 768 - 199 \approx 10{,}948 \text{ lb}$$

$$R_2 = \left(\tfrac{5}{4}\right)(1725)(11') + \left\{\frac{(8925)(4.58)}{(2)(11)^3}\left[(2)(11)^2 + (6.42)(11 + 4.58)\right]\right\}\left\{2\right\}$$

$$+ \left\{\frac{(2720)(8.75)}{(2)(11)^3}\left[(2)(11)^2 + (2.25)(11 + 8.75)\right]\right\}\left\{2\right\} \approx$$

$$\approx 23{,}719 + 10{,}504 + 5122 = 39{,}345$$





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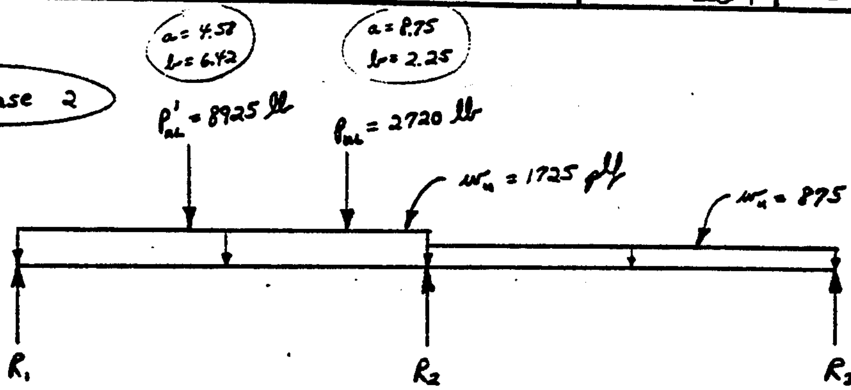
Load Case 2

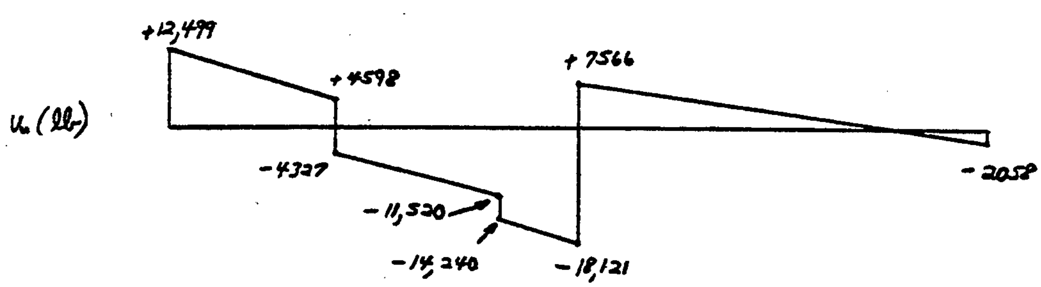


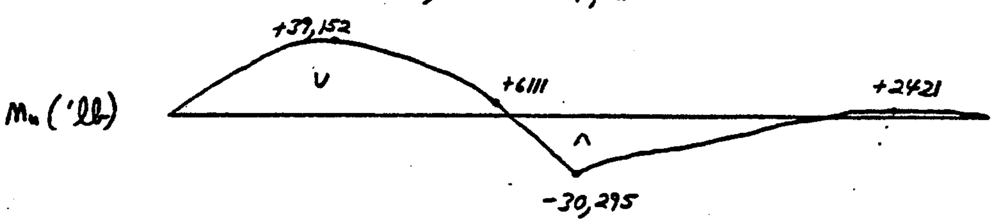
$$R_1 = \left(\tfrac{7}{16}\right)(1725)(11) - \left(\tfrac{1}{16}\right)(875)(11) + \frac{(8925)(6.42)}{(4)(11)^3}\left[(4)(11)^2 - (4.58)(11 + 4.58)\right]$$
$$+ \frac{(2720)(2.25)}{(4)(11)^3}\left[(4)(11)^2 - (8.75)(11 + 8.75)\right] \approx 8302 - 602 + 4441 + 358 =$$
$$\approx 12{,}499 \text{ lb}$$

$$R_2 = \left(\tfrac{5}{8}\right)(1725)(11) + \left(\tfrac{5}{8}\right)(875)(11) + \frac{(8925)(4.58)}{(2)(11)^3}\left[(2)(11)^2 + (6.42)(11 + 4.58)\right]$$
$$+ \frac{(2720)(8.75)}{(2)(11)^3}\left[(2)(11)^2 + (2.25)(11 + 8.75)\right] \approx$$
$$\approx 11{,}859 + 6016 + 5252 + 2561 \approx 25{,}688 \text{ lb}$$

$$R_3 = \left(\tfrac{7}{16}\right)(875)(11) - \left(\tfrac{1}{16}\right)(1725)(11) - \frac{(8925)(4.58)(6.42)}{(4)(11)^3}\left[11 + 4.58\right]$$
$$- \frac{(2720)(8.75)(2.25)}{(4)(11)^3}\left[11 + 8.75\right] \approx 4211 - 1186 - 768 - 199 = 2058 \text{ lb}$$

$\Sigma = 40{,}245$





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$$\therefore \begin{cases} M_u \text{ (max. positive)} = 39{,}152 \text{ 'lb} \\ M_u \text{ (max. negative)} = 47{,}356 \text{ 'lb} \\ V_u \text{ (max.)} = 19{,}672 \text{ lb} \end{cases}$$

for $\begin{cases} t = 10'' \\ b = 27'' \end{cases}$ $\quad d = 8'' \quad F = \dfrac{(27)(8)^2}{(12{,}000)} = .144$

$K_u = \dfrac{39.152}{.144} = 271.9$

$\rho \approx .00526$

$A_s \text{(req'd)} = (.00526)(27'')(8'') \approx 1.137^{\square''}$

$K_u = \dfrac{47.356}{.144} = 328.9$

$\rho \approx .00648$

$A_s \text{(req'd)} = (.00648)(27'')(8'') = 1.399^{\square''}$

$\therefore$ use $\begin{cases} 4 - \#6 \text{ bars in top of Beam Strips \#2 + \#5} & (A_s = 1.76^{\square''}) \\ 4 - \#6 \text{ bars in bottom of " " " + "} & (A_s = 1.76^{\square''}) \end{cases}$

$\phi V_c = (.85)(2)(\sqrt{4000})(27'')(8'') \approx 23{,}224 \text{ lb}$

$\dfrac{\phi V_c}{2} \approx 11{,}612 \text{ lb} \ll V_u\text{(max)} = 19{,}672 \text{ lb}$ $\quad \therefore$ shear reinf. req'd @ center support

$\begin{cases} \text{for Reaction } R_1, \text{ max. } V_u = (12{,}499) - (1725 \text{ plf})(1.17') = 10{,}481 \text{ lb} < \dfrac{\phi V_c}{2} \\ \qquad \therefore \text{ shear strength ok at end supports} \end{cases}$

assume #3 stirrups
$\begin{Bmatrix} A_s = .11^{\square''} \\ A_v = .22^{\square''} \end{Bmatrix}$

1 loop ok

$$\begin{cases} S_{max} = \dfrac{d}{2} = \dfrac{8''}{2} = 4'' \longleftarrow \underline{\text{governs}} \\ S_{max} = 24'' \\ S_{max} = \dfrac{(.22^{\square''})(60{,}000)}{(50)(27'')} \approx 9.8'' \\ S_{max} = \dfrac{(.85)(.22^{\square''})(60{,}000)(8'')}{(19{,}672 - 23{,}224)} \Rightarrow N.A. \end{cases}$$

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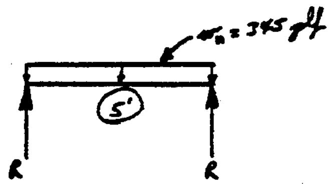
$$(13{,}071) - (1725)(x) = \frac{\phi V_c}{2} = 11{,}612 \text{ lb}$$

$$x = \frac{13{,}071 - 11{,}612}{1725} = .846' \approx 10.15'' \Rightarrow \left\{ \begin{array}{r} 10'' \\ \underline{2'\text{-}3''} \\ 3'\text{-}1'' \end{array} \right.$$

∴ extend stirrups a distance of ~ 3'-0" each side of middle wall

Design Typical Slab Reinf.

$$\left\{ \begin{array}{ll} 100 \text{ psf} & L.L. \\ 125 \text{ psf} & D.L. \end{array} \right\} \Rightarrow \left\{ \begin{array}{l} w_{uL} = (1.7)(100) = 170 \text{ psf} \\ w_{uD} = (1.4)(125) = \underline{175 \text{ psf}} \\ \qquad w_u = 345 \text{ psf} \end{array} \right.$$



$$M_u(\max) = \frac{(345)(5')^2}{(8)} \approx 1078'\text{lb}$$

$$V_u(\max) = \frac{(345)(5')}{(2)} = 862.5 \text{ lb}$$

$$F = \frac{bd^2}{12{,}000} = \frac{(12)(7)^2}{12{,}000} = .049$$

$$K_u = \frac{1.078}{.049} = 22$$

$$\rho \ll .0010 \ll \rho_{min} = .0033$$

Note: $(.0033)(12'')(7'') = .2772^{\square''}/\text{ft}$

Min. Temp. + Shrinkage Reinf in Slab ⇒ $A_s(\text{min.}) = (.0018)(12'')(10'') = .216^{\square''}/\text{ft}$

∴ Provide #4 @ 12" o.c. max., T.+B., at all other slab locations $\left(\begin{array}{c} A_s = .20^{\square''}/\text{ft} \\ T+B \end{array}\right)$

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Base Slab Design

Assume loads to foundation as follows ....

$$\text{Structure Dead Load} = \left[(23')(22')(22.17') - (10'+10')(12.5'+7')(20')\right](150\ \text{pcf})$$

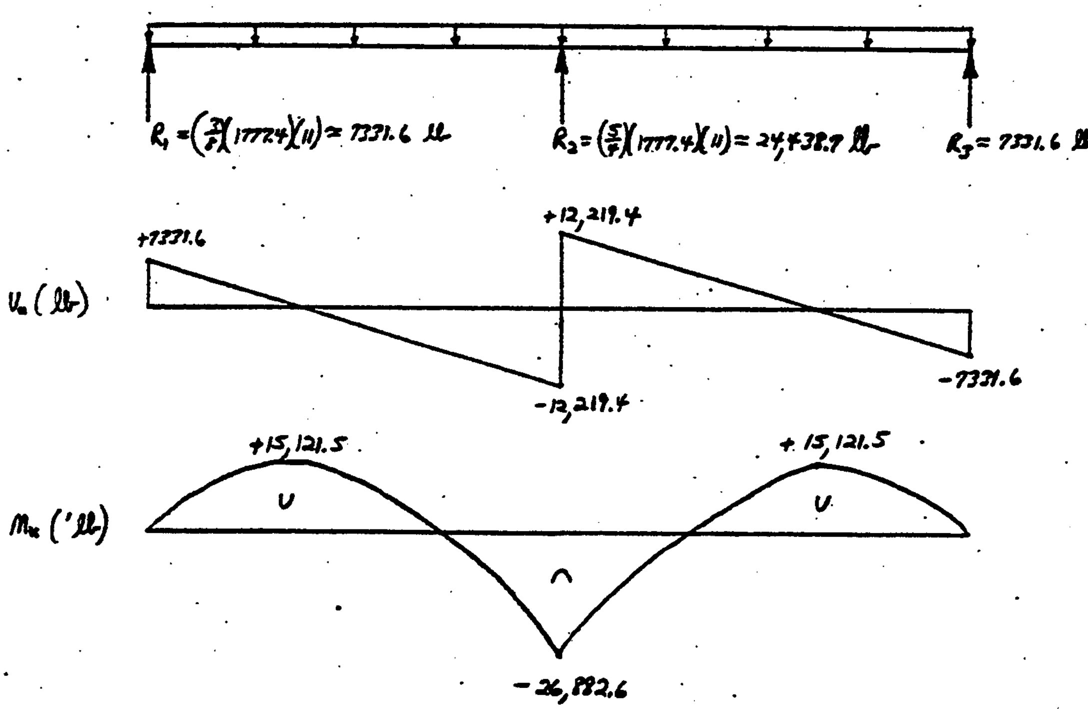
$$= (3418\ ft^3)(150\ \text{pcf}) = 512{,}703\ \text{lb}$$

$$\text{Structure Live Load} = (8)(700\ \text{lb}) + (2)(22')(23')(100\ \text{psf}) =$$

$$= 5600 + 101{,}200 = 106{,}800\ \text{lb}$$

$$w_u\ (\text{base slab}) \approx \frac{(1.4)(512{,}703) + (1.7)(106{,}800)}{(22')(23')} = 1777.4\ \text{psf}$$

Assume a 2-span continuous beam action in slab strips supported at end walls and intermediate wall.



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for $t = 12''$ $d \approx 10''$ $F \approx .100$

$K_u = \frac{15.1215}{.100} = 151.2$

$\rho \approx .00288 < \rho_{min} = .0033$

$A_s (req'd) = (.0033)(12'')(10'') \approx .396^{\square''}/ft$

$\therefore$ use #6 @ 12" ($A_s = .44^{\square''}/ft$) ⎫ @ Top of Slab
" #7 @ 18" ($A_s = .40^{\square''}/ft$) ⎭
~~" #6 @ 14" ($A_s = .38^{\square''}/ft$)~~

for $t = 12''$ $d \approx 8.5''$ $F = .07225$

$K_u \approx \frac{26.8826}{.07225} \approx 372.1$

$\rho \approx .00735$

$A_s (req'd) = (.00735)(12'')(8.5'') \approx .749^{\square''}/ft$

$\therefore$ use #6 @ 7" ($A_s = .76^{\square''}/ft$) ⎫ @ Bottom of Slab
" #7 @ 10" ($A_s = .72^{\square''}/ft$) ⎭

Min. Temp. + Shrinkage $\Rightarrow$ $A_s = (.0018)(12'')(12'') = .259^{\square''}/ft$

use #4 @ 18" ($A_s = .13^{\square''}/ft$) @ Bottom of Slab

$\perp$ to main reinf.

$A_s = (\rho_{min})(b)(d) = (.0033)(12'')(9'') = .3564^{\square''}/ft$

use #6 @ 14 ($A_s = .38^{\square''}/ft$) @ Top of Slab
" #7 @ 18" ($A_s = .40^{\square''}/ft$)

$\phi V_c = (.85)(2)(\sqrt{4000})(12'')(10'') = 12,902$ lb $> V_u = 12,219$ lb

✓ ok